U.S. ARMY
MATERIEL COMMAND

PROGRAM MANAGER
RMA CONTAMINATION CLEANUP

— COMMITTED TO PROTECTION OF THE ENVIRONMENT —

Rocky Mountain Arsenal
Information Center
Commerce City, Colorado

EBASCO SERVICES INCORPORATED
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VOLUME IV
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TECHNICAL SUPPORT FOR ROCKY MOUNTAIN ARSENAL

FINAL WATER REMEDIAL INVESTIGATION REPORT

VERSION 3.3 - VOLUME IV

July 1989
Contract Number DAAK11-84-D-0016
and DAAA-15-88-D-0024

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13. ABSTRACT *(Maximum 200 words)*

THIS WATER REMEDIAL INVESTIGATION IS A COMPILATION, INTEGRATION, AND INTERPRETATION OF GROUND WATER AND SURFACE WATER STUDY RESULTS OBTAINED FROM SPECIFIC TASKS AND DESIGNED TO PROVIDE A COMPREHENSIVE ASSESSMENT OF CONTAMINATION BOTH ON- AND OFF-POST.

THE RI IS DIVIDED INTO FIVE VOLUMES:

1. INTRODUCTION TO THE PROJECT, DESCRIPTION OF THE ENVIRONMENTAL SETTING, AND ASSESSMENT OF THE NATURE AND EXTENT OF CONTAMINATION
2. GEOLOGICAL AND HYDROLOGIC DATA, TASK 44 DATA, CHEMISTRY DATA, AND INFORMATION PERTAINING TO HYDROCHEMICAL PROPERTIES AND HYDROLOGIC CALCULATIONS
3. APPENDIX F WHICH IS A DETAILED DESCRIPTION OF GEOLOGY, HYDROLOGY, CONTAMINANT DISTRIBUTION, AND HISTORICAL GROUND WATER AND SURFACE WATER PROGRAMS
4. COMMENTS AND RESPONSES FOR THE DRAFT FINAL RI
5. PLATES REFERENCED IN VOLUMES I AND III.

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TECHNICAL SUPPORT FOR
ROCKY MOUNTAIN ARSENAL

FINAL
WATER REMEDIAL INVESTIGATION REPORT

(Version 3.3)
Volume IV

July 1989

Contract Number DAAK11-84-D-0016
and DAAA-15-88-D-0024

Prepared By

EBASCO SERVICES INCORPORATED
R. L. Stollar & Associates, Inc.
Hunter/ESE, Inc.
Harding Lawson Associates

Prepared For

U.S. Army Program Manager's Office for
Rocky Mountain Arsenal Contamination Cleanup

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VOLUME V

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ACRONYMS AND ABBREVIATIONS

ac-ft	acre-feet
ac-ft/mo	acre-feet per month
ac-ft/yr	acre-feet per year
ACL	alternative concentration limit
Al	A lithologic zone - lower
Am	A lithologic zone - middle
ARAR	Applicable or Relevant and Appropriate Requirement
Army	Department of the Army
As	A lithologic zone - channel
ASTM	American Society for Testing and Materials
ASY	apparent specific yield
atm-m^3/mole	atmosphere-cubic meter per mole
Au	A lithologic zone - upper
AWQC	ambient water quality criteria
12DCLE	1,2 dichloroethane
BTZ	benzothiazole
CC	Contamination Control
CCC	Colorado Climate Center
CCl_4	Carbon Tetrachloride
CDH	Colorado Department of Health
CDM	Camp Dresser & McKee, Inc.
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF&I	Colorado Fuel and Iron
cfs	cubic feet per second
CH_2Cl_2	Methylene Chloride
cm/sec	centimeters per second
CMP	Comprehensive Monitoring Program
COE	U.S. Army Corps of Engineers
CPMS	chlorophenylmethyl sulfide
CPMSO	chlorophenylmethyl sulfoxide
$CPMSO_2$	chlorophenylmethyl sulfone

CRL	certified reporting limits
CSU	Colorado State University
CSU-GWFlow	Colorado State University Groundwater Flow Model
CWP	Composite Well Program
CWQ	Clean Water Act
DBCP	Dibromochloropropane
11DCE	1,1-dichloroethylene
11DCLE	1,1-dichloroethane
12DCE	trans-1,2-dichloroethylene
DCPD	Dicyclopentadiene
DIMP	Diisopropylmethyl phosphonate
1,4-DITH	1,4-dithiane
DMDS	dimethyldisulfide
DMMP	dimethylmethyl phosphonate
DOJ	Department of Justice
EA	Endangerment Assessment
EDL	elevated detection limit
EPA	U.S. Environmental Protection Agency
ESE	Environmental Science and Engineering, Inc.
FCP	First Creek Paleochannel
Fm	Formation
FRICO	Farmer's Reservoir and Irrigation Company
FS	Feasibility Study
ft	feet
ft/day	feet per day
ft/ft	feet per foot
ft/sec	feet per second
ft/yr	feet per year
ft^3	cubic feet
FY87	Fiscal Year 1987
gal/ft^2	gallons per square foot
GB	nerve gas comprised of Sarin

GC	gas chromatograph
G/ml	gram per milliliter
GC/MS	gas chromatography/mass spectrometry
gpd/ft	gallons per day per foot gpd/ft^2gallons per day per square foot
gpm	gallons per minute
H	Henry's Law Constant
HCCPD or CL_6CP	hexachlorocyclopentadiene
HGU	Hydrogeologic unit
HLA	Harding Lawson Associates
HSL	Hazardous Substance List
ICAP	inductively-coupled argon plasma
ICS	Irondale Containment System
ID	inside diameter
in/hr	inches per hour
in/mo	inches per month
IRA	Interim Response Action
ISP	Initial Screening Program
K	hydraulic conductivity
K_{oc}	organic carbon partition coefficient
K_d	partition coefficient
K_{ow}	octanol/water partition coefficient
LA	Lignite A
LB	Lignite B
lbs/ft^3	pounds per cubic foot
LC	Lignite C
LD	Lignite D
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
mg/l	milligrams per liter
mi	miles
MIBK	methylisobutyl ketone
MKE	Morrison-Knudsen Engineers, Inc.

mm	millimeter
mph	miles per hour
msl	mean sea level
NBCS	North Boundary Containment System
NBTP	North Boundary Treatment Plant
NBW	north boundary west
NTC	nontarget compounds
NWBCS	Northwest Boundary Containment System
NWBP	Northwest Boundary Paleochannel
O&M	operation and maintenance
O_3	ozone
PAS	Parties and the State
OCP	organochlorine pesticide
OD	outside diameter
^oF	degrees Farenheit
OXAT	oxathiane
OX/DITH	Combined oxathiane and dithiane
PCE	tetrachloroethylene
PI	plasticity index
PID	photoionization detector
PMO-RMA	U.S. Army Program Manager's Office for Rocky Mountain Arsenal Contamination Cleanup
PMSO	Program Manager Staff Office
p,p'-DDE	p,p'-1,1-dichloro-2,2-bis(4-chlorophenyl)-ethylene
p,p'-DDT	p,p'-dichlorodiphenyltrichloroethane
PPLV	Preliminary Pollutant Limit Value
ppm	parts per million
psi	pounds per square inch
PVC	polyvinyl chloride
QA1	Paleochannels in terrace gravels
QA2	Paleochannels in eolian deposits (w/gravels)
QA3	Silty terrace gravels and coarse sand
QA4	Paleochannels in eolian deposits (w/o gravels)

QAE	Eolian deposits
QA/QC	Quality Assurance/Quality Control
QC	Quality control
QT	Quarternary terrace gravels
RCI	Resource Consultants, Inc.
RCRA	Resource Conservation and Recovery Act
R_f	Retardation factor
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RIC	RMA Information Center
RMA	Rocky Mountain Arsenal
RMACCPMT	Rocky Mountain Arsenal Control Management Team
ROD	Record of Decision
SACWSD	South Adams County Water and Sanitation District
SAR	Study Area Report
SARA	Superfund Amendments and Reauthorization Act
SCC	Shell Chemical Company
SCS	Soil Conservation Service
SDWA	Safe Drinking Water Act
Shell	Shell Chemical Oil Company
SO_2	Sulfur Dioxide
sq mi	square mile(s)
STP	Sewage Treatment Plant
SW/GW	surface water/groundwater
T	transmissivity
111TCE	1,1,1-trichloroethane
112TCE	1,1,2-trichloroethane
TCLEE	tetrachloroethylene
TIC	tentatively identified compounds
TKd	Denver Formation
TRCLE	trichloroethylene
TSP	total suspended particulates

lu	number one upper zone in the Denver Fm
ug/g	micrograms per gram
ug/l	micrograms per liter
UFS	Unconfined Flow System
UNK	unknown
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USCS	Unified Soil Classification System
UTM	Universal Transverse Mercator
VC	volcaniclastic interval
VCE	clay-rich zone stratigraphically equivalent to VC
VOA	volatile organic aromatics
VOC	volatile organic compounds
VOH	volatile organohalogens
WES	U.S. Army Corps of Engineers Waterways Experiment Station
WRI	Water Remedial Investigation
WY87	Water Year 1987

APPENDIX G
COMMENTS AND RESPONSES TO THE WATER
REMEDIAL INVESTIGATION,
DRAFT FINAL REPORT
(VERSION 2.2)
MARCH 1989

The Water Remedial Investigation, Draft Final Report (Version 2.2) was distributed on March 15, 1989 to all Organizations and the State. Comments were received from the U.S. Environmental Protection Agency on April 28, 1989; Shell Oil Company on April 1, 1989; and the Colorado Department of Health on May 5, 1989. All written comments and formal responses are incorporated in the following appendix. Additional Water Remedial Investigation comments and responses that have not appeared in previous reports or have not been transmitted previously are included in this appendix. These include comments from the Colorado Department of Health, dated September 8, 1988, comments from the U.S. Environmental Protection Agency, dated June 27, 1988, December 20, 1988, and July 1, 1988, and comments from Shell Corporation dated October 3, 1988.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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APR 28 1989

Mr. Donald L. Campbell
Office of the Program Manager
Rocky Mountain Arsenal
ATTN: AMXRM-PM
Commerce City, Colorado 80022-2180

Re: Rocky Mountain Arsenal (RMA)
Draft Final Water Remedial
Investigation Report, March 1989.

Dear Mr. Campbell:

We have reviewed the above referenced document and found it to be a very comprehensive presentation of the regional ground water flow at RMA. We have the enclosed specific comments. We particularly wish to highlight our concerns in the following areas:

1. The report should provide a better reference for all of the data, calculations and conclusions associated with the values which are presented for the effective distributed rates of recharge for the RMA. In addition, the report should present a worst case scenario for major precipitation events.

2. The text should indicate where volatilization, transformation, or degradation processes have been observed or suspected to occur on the RMA. This presentation should include which daughter products are being observed and at which locations.

3. The discussion relating to historical data on fluoride should include specific details on the movement over time of the plume. The specific area of concern is the portion of the plume moving toward the north which contains 10 mg/l fluoride.

Please contact Linda Grimes at (303) 293-1262, if you have questions on this matter.

Sincerely,

Connally Mears

Connally Mears
EPA Coordinator
for Rocky Mountain Arsenal Cleanup

Enclosure

cc: Jeff Edson, CDH
David Shelton, CDH
Vicky Peters, CAGO
Lt. Col. Scott P. Isaacson
Chris Hahn, Shell
R. D. Lundahl, Shell
David Anderson, DOJ

EPA REVIEW COMMENTS
WATER REMEDIAL INVESTIGATION REPORT
DRAFT FINAL
Version 2.2
March 1989

GENERAL COMMENTS

Comment 1. The report should provide a better reference for all of the data, calculations and conclusions associated with the values which are presented for the effective distributed rates of recharge for the RMA. In addition, the report should present a worst case scenario for major precipitation events.

Response Text describing recharge at RMA (Section 2.4.4 and Appendix F, Section 2.4.3.3) has been modified to provide better reference to supporting documents. A worst case scenario for major precipitation events has been included in Section 4.2 of the report.

Comment 2. The text should indicate where volatilization, transformation, or degradation processes have been observed or suspected to occur on the RMA. This presentation should include which daughter products are being observed and at which locations.

Response Evidence has been presented of volatilization, transformation, or degradation processes operating in water at RMA in the revised Section 4.4.2. The presentation includes descriptions of daughter products. Table 4.3 and Figure 4.2 also have been added.

Comment 3. The discussion relating to historical data on fluoride should include specific details on the movement over time of the plume. The specific area of concern is the portion of the plume moving toward the north which contains 10 mg/l fluoride.

Response Migration of fluoride north of Basin F has been described in the revision of Section 4.6.4.

VOLUME I, SECTION 1.0

Comment 1. Page 1-2, second paragraph. Second Creek should be shown on Figure 1.1 as it is a referenced boundary.

Response Second Creek has been added to Figure 1.1.

APPENDIX F, Section 1.0

Comment 2. Page 1-10, third paragraph. Were Shell data incorporated into this report?

Response — Contaminant distribution presented in this report is based primarily on data obtained during FY87. Shell/MKE data were not available for this time period. Data obtained by Shell/MKE during FY88 are more appropriately included with the 1988 Annual Ground-water Report of CMP. That report currently is in preparation. For purposes of the Water RI, data obtained by Shell/MKE during FY88 have been used as qualitative information in areas such as South Plants where other water-quality data are limited. Efforts to use water-quality data obtained by Shell/MKE in combination with data from other sources also have been hampered by large differences in Certified Reporting Limits. Therefore, Shell/MKE data are not used directly in the Water Remedial Investigation Report. Shell/MKE data are included in the South Plants SAR.

Comment 3. Page 1-10, second paragraph. Are these data/results in this report?

Response — Conclusions of these tasks are included within the Water RI report. However basic data for these tasks are not presented in this report.

Comment 4. Figure 1.4-2. The Task 42 area is not shown on this figure.

Response — The Task 42 area has been added to Figure 1.4-2.

VOLUME I, SECTION 2.0

Comment 5. Page 2-8, Table 2.2. The text supporting this table should indicate how the "best estimate" of hydraulic conductivity was derived.

Response — For hydrogeologic units with a substantial number of aquifer tests, the best estimates are the median values of those tests. These units are QT, QA1, QA2 and QA3. Aquifer test data for the remaining units, particularly data from multiple-well tests, are more limited. In these cases the range is based on test results, while the best estimate reflects the judgement of the hydrogeologists who compiled the information. A note to this effect has been added to the text.

Comment 6. Figure 2.3. In the legend for this figure, unit QA4 should be labeled "w/out" gravel according to Table 2.2. Also, why is there a contour interval designation for this figure? This comment applies to the corresponding figure in Appendix F also.

Response — The explanation for QA4 has been changed as indicated in the comment. Designation of a contour interval in the explanation was an error and has been deleted.

Comment 7. Page 2-16, first paragraph. Vertical leakage estimates from the unconfined flow system (UFS) to the Denver Formation should be made as the necessary information (vertical hydraulic conductivity, vertical gradients) are available. This comment applies to Section 2.4.3.5 in Appendix F also.

Response A single estimate of vertical hydraulic conductivity is available from a pumping test near the north boundary. It is not known if the resulting estimate of 4.1 X 10^{-5} ft/day is representative of RMA in general. Therefore, including estimates of effective leakage throughout RMA based on this value could be misleading.

Appendix F, Section 2.0

Comment 8. Table 2.3-4. It appears that this table should be Table 2.3-3. This applies to the references in the text also.

Response Table 2.3-3 is characteristic Flow Statistics for Stream Gaging Stations at RMA. It is referenced on p. 2-32. Table 2.3-4 is RMA Monthly Water Balance Summary. It is referenced on p. 2-34.

Comment 9. Page 2-47, last paragraph. Reference should be provided for the claystone hydraulic conductivity values presented. The values which are presented appear to conflict with the values shown on Table 2.4-1 for fractured claystone (3.4 to 3.6 feet per day) based on pumping test results. Clarification is requested.

Response The paragraph is not based on aquifer test data obtained at RMA. It has been replaced with a description of conditions specific to RMA.

Comment 10. Page 2-53, third paragraph. Figure 2.4-11 shows the direction of vertical gradients between sandstones, not Figure 2.4-13 as indicated in the text.

Response The error in figure references has been corrected.

Comment 11. Page 2-56, second paragraph. Plate 17 corresponds to Figure 2.4-17, not Plate 13 as indicated in the text.

Response The error in plate references has been corrected.

Comment 12. Figure 2.4-19a. This figure is not clear. It seems to show two years worth of data, yet the text indicates that it illustrates three years worth of data (on page 2-58, last paragraph). It is not clear which symbol represents which well or year. Clarification is requested.

Response The text has been changed to indicate that seasonal fluctuations for two years are shown. A single symbol is used for all data illustrated in the figure. The purpose of the figure is to show average seasonal water table fluctuation.

Comment 13. Page 2-61/Table 2.4-5. Are the best estimates of hydraulic conductivity averages of the values shown in Appendix B, Table 1? An explanation is requested. Since only one aquifer test was performed in unit Qe, and the result was 0.004 cm/sec, how was the best estimate of 0.02 cm/sec for this unit derived?

Response See response to comment 5. Although only one aquifer test conducted with multiple observation wells was available to characterize the eolian

unit, the range was established on the basis of slug-test data presented in Appendix B.

Comment 14. Page 2-68, first paragraph. Additional information should be provided on the MKE recharge estimate. Were monthly calculations performed? Why is the source of this estimate referenced to HLA on Table 2.4-6? The discussion should be expanded to indicate how recharge varies seasonally and how it may vary depending on topography (i.e., recharge may be more in areas where surface water ponds or beneath ditches).

Response Additional information has been provided in the text as suggested. Reference to HLA is incorrect and has been changed to MKE. Spatial and temporal variations in recharge have been described. The MKE estimates represent average rates over a six-year period and are applicable to quasi steady-state conditions. MKE also refers to these estimates as preliminary estimates subject to refinement as needed.

Comment 15. Page 2-70, first paragraph. The text should be expanded to discuss how recharge to the unconfined flow system from subcropping Denver Formation sandstones was estimated.

Response A paragraph has been added describing how recharge from subcropping Denver sandstone was estimated.

Comment 16. Page 2-74, top of page. A summary of the methods and assumptions made to estimate the discharge volumes does not appear to be in Appendix B. Clarification is requested.

Response The reference to Appendix B has been removed.

VOLUME 1, SECTION 3.0

Comment 17. Page 3-6, first paragraph. The text should also discuss the DCPD plume shown in the South Plants area on Figure 3-4.

Response The paragraph has been modified to include discussion of the plume migrating south from South Plants.

Comment 18. Page 3-7, first paragraph. Recent Shell data for the South Plants area for all compounds should be included in this report.

Response See response to comment 2.

APPENDIX F, Section 4.0

Comment 19. Section 4.1. The discussion of historic surface water contaminant distributions should also include the results of studies conducted in specific areas in investigations other than those conducted under Tasks 4/44.

Response — Discussions of surface water contaminant distribution in specific areas are included in applicable Study Area Reports. Hydrologic description of specific areas are not within the scope of the Water Remedial Investigation Report which focuses on regional data analysis.

Comment 20. — Page 4-8, last paragraph. This discussion is presumably referring to station 08001. The first sentence of this paragraph appears to be in error as DIMP was not detected at this location in spring 1987 (Table 4.1-2) or between fall 1985 and fall 1987 (Table 4.1-3). In what investigation was DIMP detected between 1976 and 1985? Clarification is requested. The text should state that this compound was not detected recently, and in which investigation it was detected.

Response — Text has been changed to emphasize data collected since 1985. Isolated detections of this compound were obtained prior to 1985 as part of the 360° Program.

Comment 21. — Page 4-13, last paragraph. The text should state in which on-post areas data prior to third quarter 1987 were used to estimate the contaminant distribution.

Response — Data obtained prior to Third Quarter 1987 were used in areas where information from 1987 is limited. These areas are contaminant specific and are identified as appropriate in discussions of individual contaminants. Data for Third Quarter 1987 are limited in the South Plants area, south of Basin C, and near Basin D.

Comment 22. — Page 4-35, Section 4.2.2.1. The discussion on historical dieldrin contamination is confusing. It appears that past concentrations are being discussed, however the tense used implies that present concentrations are being discussed. Is the "second plume" mentioned in the last paragraph on page 4-35 referring to a plume in the Denver Formation? It appears that it may be since the Denver Formation is being discussed in the previous paragraph. In the same regard, it is not clear on page 4-36 whether the UFS or the Denver are being discussed, and whether past or present contamination are being discussed. Clarification is requested.

Response — The Section has been reorganized to eliminate confusion. Tense is now consistent. Discussion of contamination in the Denver Formation follows discussion of the Unconfined Flow Systems. References to FY87 data and contaminant distribution have been deleted or inserted as appropriate in Section 4.2.2.2.

Comment 23. — Page 4-37, third paragraph. It appears that only the last three plumes bulleted are discussed in the text. Each plume identified should be discussed.

Response — Discussion has been added of the first two bullets.

Comment 24. — Page 4-40, second paragraph. The text indicates that the northern plume was inferred, yet on Figure 4.2-2 no dashed lines are shown. Clarification is requested.

Response — Figure 4.2-2 has been changed to show the extent of the plume as inferred.

Comment 25. — Page 4-42, third full paragraph. It appears that the dieldrin detections shown on Figure D-30 other than for well 24171 should be denoted by triangles. Presently these detections are denoted by circles implying that they are in confined Denver zone 2.

Response — Figure D-30 was in error and has been changed as suggested.

Comment 26. — Page 4-42, fourth paragraph. Since these detections are located relatively close to the plumes shown on Figure 4.2-2, it would appear that the UFS cannot be ruled out as a source. This potential should be discussed in the text.

Response — The Unconfined Flow System is a possible source for this contamination. However nearby wells completed in zone 2 are not contaminated by Dieldrin. The text has been changed to reflect these ideas.

Comment 27. — Page 4-41, second paragraph. The text should discuss potential sources for the isolated off-post detections.

Response — Before identifying possible sources of contamination, the presence of contamination must be confirmed by repeated sampling. Many isolated wells with detectable levels of contaminants are included as part of the CMP sampling network for FY88. Most isolated detections have not been confirmed during the first year of CMP sampling.

Comment 28. — General Comment on all Ground Water Contaminant Distributions. Each discussion should include a brief summary which compares the observed third quarter FY87 distribution with the historical distribution. Things to be noted would include whether the same compounds had been observed at the same locations; how concentrations and ranges had changed; how plumes had moved/changed; and why results may be different (analytical methods, for example). The overall objective of such a discussion would be to provide an indication of whether past contaminant distributions were verified in subsequent samplings.

Response — A description of historical distribution is presented in the Water Remedial Investigation Report for each contaminant. Comparisons between historical distributions and Third Quarter FY87 distributions are not appropriate, primarily due to differences in well sampling networks. One of the principal objectives of the Comprehensive Monitoring Program (CMP) is to confirm or validate the contaminant distributions identified by previous sampling. The 1988 CMP Annual Report, currently in preparation, includes summaries comparing distributions observed in 1988 and 1987.

Comment 29. — Page 4-45, third paragraph. Potential sources of the isolated endrin detections should be discussed.

Response — See response to comment 27.

Comment 30. Page 4-47, last paragraph. It appears that the endrin detections shown on Figure D-33 other than for well 23218 should be denoted by triangles. Presently these detections are denoted by circles implying that they are in confined Denver zone 2.

Response — Figure D-33 was in error and has been changed as suggested.

Comment 31. Page 4-48. The text should briefly discuss the remaining pesticide contaminant distributions in ground water, especially PPDDE (Figure D-13). What is the source of this compound so far up gradient?

Response — Contaminants illustrated in figures D-10 through D-26 occur as isolated detections. In most cases, sources are the same as identified previously for Dieldrin. The contaminant PPDDE (Figure D-13) is not hydraulically upgradient of previously identified sources.

Comment 32. Page 4-53, second paragraph. The text should discuss why the detections in Denver zone 2 do not appear to be related to detections in overlying Denver zones or the UFS.

Response — The statement in the text is incorrect and has been changed to indicate a possible relation to overlying units.

Comment 33. Page 4-54, first paragraph. The text should indicate where this compound did occur historically and what concentrations were, even if analyses were only reported on a limited basis.

Response — The text incorrectly indicated that the compound had been detected in the past. Discussion has been changed as appropriate.

Comment 34. Page 4-57, fourth paragraph. Table 4.2-9 and the text present one detection of benzothiazole in Denver zone 1, yet Figure D-59 shows two detections of this compound in this zone. Clarification is requested.

Response — Figure D-59 has been corrected to agree with text.

Comment 35. Page 4-58, second paragraph and Page 4-63, second paragraph. Table 4.2-10 indicates that this compound group is also present in Denver zone 5. Clarification is requested.

Response — Table 4.2-10 has been corrected to agree with text and figures.

Comment 36. Page 4-63, last paragraph, fourth sentence. The Denver zone designation is missing; it appears that it is zone 1u.

Response — The zone designation has been added; the correct zone designation is lu.

Comment 37. Page 4-64, first paragraph. Based on Figures D-67 and D-69, it appears that there was more than one organosulfur detection in Denver zone 2.

Clarification is requested. Also, could the basins area be the source of the detection in zone 2?

Response — The paragraph was incorrect and has been rewritten to indicate more widespread contamination of zones 1 and 2. Contaminated ground water in the Unconfined Flow System beneath the basins is the likely source of the detection in zone 2.

Comment 38. Page 4-66, second paragraph. The text should discuss potential sources for the isolated VAO detections noted.

Response — See response to comment 27.

Comment 39. Page 4-66, third paragraph. Recent Shell data (1988) for the South Plants area should be incorporated into the assessment.

Response — See response to comment 2.

Comment 40. Page 4-67, top of page. What is the source of the plume described?

Response — Basin F probably was the source of this plume. However contaminant mass also may have been introduced from Basin C. A discussion of source areas is given in Volume I, Section 4.5.

Comment 41. Page 4-68, top of page. The text should discuss potential sources of this plume.

Response — The text has been modified to identify contamination sources.

Comment 42. Page 4-69, second paragraph. Is the very high concentration of benzene that is "apparently isolated" still believed to be so given third quarter FY87 data and the more recent data collected by Shell in the South Plants area? Was this detection verified in subsequent sampling events?

Response — The high value for benzene in the Denver aquifer obtained as part of the ISP is roughly coincident with the benzene plume identified by Shell/MKE in the Unconfined Flow System. However the detection was not confirmed by subsequent sampling.

Comment 43. Page 4-72, fourth paragraph, last sentence. The reference should be to Figure 4.2-11, not 4.2-10. Also, what is the source of the benzene detected in Zone A?

Response — Reference to the figure has been changed. Text has been added indicating that the Unconfined Flow System probably is the source of contamination in Zone A.

Comment 44. Page 4-73, third paragraph. The reference to unconfined Denver in the first sentence should be confined, based on Table 4.2-11 and the text on the previous page. Also, the last sentence should say "no detectable benzene".

Response — The text was in error and has been corrected as suggested.

Comment 45. Page 4-77, second paragraph. The text should also address the isolated chlorobenzene detection in Section 33.

Response — The text has been modified to identify the isolated detection of chlorobenzene in Section 33.

Comment 46. Section 4.2.7.3. The text should discuss potential sources for all the isolated detections in the UFS mentioned in this section, both on and off post. It appears that the off post isolated detections in the northwest area may be spatially related.

Response — See response to comment 27. Some samples were obtained below CRL within the areas suggested to be spatially correlated. Therefore data are not contoured.

Comment 47. Page 4-78, top of page. The text should address the relatively large detection of chlorobenzene in Denver zone 1U. Also, Table 4.2-12 indicates that there were two chlorobenzene detections in confined Denver zone 1 and one detection in unconfined Denver zone 1, however Figure D-82 shows four confined Denver zone 1 detections. Clarification is requested and the text should be revised accordingly.

Response — The text has been modified to discuss chlorobenzene contamination in zone 1u. Figure D-82 has been corrected to correspond with Table 4.2-12.

Comment 48. Page 4-78, third paragraph. The third sentence does not appear to be true, based on examination of Table 4.2-12. The last sentence of this paragraph should be supported with the associated calculations.

Response — Both the third and last sentences of this paragraph cannot be supported by existing data and have been deleted.

Comment 49. Page 4-79, third paragraph. The potential sources of isolated chlorobenzene detections in the Denver Formation should also be addressed.

Response — See response to comment 27. Sources of chlorobenzene in the Denver Formation probably include contaminated ground water in the Unconfined Flow System.

Comment 50. Page 4-81, second paragraph. Why were the ISP isolated Denver Formation VHO detections so low compared to the Shell historical data discussed in the previous paragraph?

Response — Differences in concentrations are attributable almost exclusively to differences in sampling well locations.

Comment 51. Page 4-84, first paragraph. Supporting calculations should be provided for the conclusion drawn in the second to last sentence.

Response — Calculations of velocity and partitioning behavior are not needed to justify the interpretation shown in Figure 4.2-14. Well control is sufficient. Therefore, the second to last sentence has been deleted.

Comment 52. Page 4-85, first paragraph. Potential sources of the isolated detections mentioned should be discussed.

Response — See response to comment 27. Most of these isolated detections have not been confirmed during CMP sampling.

Comment 53. Section 4.2.8, General Comment. The other VHOs detected (DCE, etc.) should also be briefly discussed in this section. This should include discussion of the plumes shown in Appendix D.3 and the point plots shown in Appendix D.4 and D.5. For example, Figure D-22 seems to indicate some relationship amongst the 1,1-DCA detections in the western tier. The source of the methylene chloride detections shown on Figure D-21 should be discussed. Are these believed to be laboratory artifacts or real detections? Methylene chloride detections in the Denver Formation should also be discussed. These distributions should be incorporated into biodegradation discussions in Section 4.0 of Volume 1, where appropriate.

Response — Text describing relations among the various compounds in this group has been added to Section 4.4, Volume I to illustrate transformation and degradation processes. Methylene chloride has been discussed briefly in the new text as well. Section 4.3, Volume III indicated that methylene chloride appeared frequently in lab blanks and is suspected to be an artifact.

Comment 54. Page 4-89, first paragraph. The text should discuss the potential sources of the isolated detections mentioned.

Response — See response to comment 27. Most of the isolated detections have not been confirmed during CMP sampling.

Comment 55. Page 4-89, second paragraph. The supporting contaminant transport velocities should be included.

Response — The statement in the text was incorrect. The text has been changed to indicate that the sporadic distribution of detections precludes contouring a continuous plume with confidence.

Comment 56. Page 4-89, fourth paragraph. Chloroform was also detected in confined Denver zone 1, according to Table 4.2-13.

Response — The text has been revised to include chloroform detections in Denver zone 1.

Comment 57. Page 4-89, last paragraph. Figure D-99 shows six detections of chloroform in zone VC/VCE, and Figure D-100 shows seven detections of chloroform in zone A and also shows this compound in eastern Section 1,

not western Section 1 as indicated in the text. Clarification is requested. The text should discuss potential sources of the isolated detections in zone A (those which are not already discussed in the text), and zones 2, 5, and 6.

Response — Figures D-99 and D-100, Table 4.2-13, and the text have been corrected and information has been made consistent. Text has been added indicating that isolated detections not associated with chloroform contamination in overlying units are being resampled under CMP to confirm contamination.

Comment 58. Page 4-94, third paragraph. The text indicates that the EPA data are presented as distribution plots; however, Figure 4.2-16 appears to show that these data were contoured. Clarification is requested.

Response — The text has been changed to indicate that EPA data are contoured.

Comment 59. Page 4-95, third paragraph. Table 4.2-14 shows all four wells as being confined, not three as indicated in the text. Figure D-107 shows one well in Zone A, however Table 4.2-14 shows two wells in this zone. Figure D-109 shows two wells in Zone 1, yet Table 4.2-14 shows one well in this zone. Clarification is requested. Finally, what is the potential source of the TCE detected in Section 26?

Response — Figure D-109 and Table 4.2-14 have been changed to agree with the text. The source of TCE in section 26 may be Basins C or F, or sewers east of these basins. However, evidence to support this designation is lacking in the Unconfined Flow System. Consequently, contamination is being confirmed by repeated sampling during CMP.

Comment 60. Page 4-95, last paragraph. The text should discuss potential sources of the isolated detections mentioned.

Response — See response to comment 27. Most isolated detections have not been confirmed during CMP sampling.

Comment 61. Page 4-99, second paragraph. What is the potential source of the PCE plume in the western tier?

Response — No on-post source of this contaminant has been identified along the Western Tier pathway. Upgradient wells near the RMA boundary show elevated concentrations of this contaminant. However, soils in the vicinity of or upgradient of these wells do not show contamination. An unidentified off-post source is suspected. Soils beneath the open storage yard in Section 4 show contamination. However, ground water beneath and downgradient of this site shows no contamination.

Comment 62. Page 4-99, last paragraph. Table 4.2-15 shows three confined Denver detections, not four as indicated in the text. Clarification is requested.

Response — The text has been changed to be consistent with Table 4.2-14 and Figures D-113 through D-116.

Comment 63. Page 4-100, second paragraph. Table 4.2-15 does not show any detections in zone 1u. Clarification is requested.

Response The third sentence has been modified to eliminate the inference that contaminant was detected in zone 1u.

Comment 64. Page 4-105, third paragraph. Figure D-137 appears to show a confined Denver zone 1 detection which is probably supposed to be unconfined.

Response The confined detection shown in Figure D-137 has been corrected to indicate that it is unconfined.

Comment 65. Page 4-106, Section 4.2.10.1. It appears that ISP detections of DCPD contamination in the Denver Formation were not verified in later sampling episodes. The text should address possible reasons why this occurred.

Response Sampling technique, laboratory error, or other sources of variability may have been the cause. Until adequate sampling data are available through CMP and a quantitative analysis is conducted, speculation is inappropriate on causes of isolated detections.

Comment 66. Page 4-107, top of page. The text should address what the Denver Formation occurrences may be related to, if not to occurrences in the alluvial aquifer.

Response As indicated by comment 65, detections in the Denver aquifer during the ISP were not generally confirmed by subsequent sampling.

Comment 67. Page 4-107, first and second paragraphs. The text should address possible reasons why historical distributions were not confirmed.

Response See response to comment 65.

Comment 68. Section 4.2.10.2. The text should also discuss the DCPD plume shown in South Plants on Figure 4.2-19. This is especially important since this compound was historically detected in this area in the Denver Formation. The Denver Formation contamination in this area may well be related to UFS contamination in the same area.

Response The text has been changed to identify the plume south of South Plants. Response 65 addressed the belief that historical detections of this contaminant may be related to the plume.

Comment 69. Page 4-11, second paragraph. Figure D-140 shows a confined Denver zone 1 DCPD detection. Clarification is requested.

Response Figure D-140 has been changed to coincide with Table 4.2-17.

Comment 70. Page 4-118, last paragraph and Page 4-119, first two paragraphs. Why no clear relationship between contamination in the UFS and the Denver

Formation is apparent should be explained in more detail, since DIMP was observed in the UFS above detections in the Denver Formation.

Response — The text was incorrect and has been changed to reflect the idea presented in the comment.

Comment 71. — Page 4-125. The discussion relating to historical data on fluoride should include specific details on movement over time of the plume. The specific area of concern is the portion of the plume moving towards the north which contains 10 mg/liter fluoride. The narrative should discuss movement of the area of high concentrations over time. The narrative should also discuss movement of fluoride out of Section 36 towards both the north and northwest.

Response — Comparison of Water RI data with Initial Screening Program data shows that migration of the fluoride plume north of Basin F has been very slow in recent years. Comparisons of Initial Screening Program data with data presented by Spaine (1984) and historical data are of limited use because of differences in the well sampling network. The same conclusions can be made regarding the movement of fluoride in section 36. A principal objective of the CMP is to relate historical data, Water RI data and CMP data in order to evaluate rates of migration. The 1988 annual ground-water report of CMP, currently in preparation, includes an extensive discussion of this topic. Because the CMP discussion is based on data not available in the Water RI Report, it is more complete than in the Water RI Report.

Comment 72. — Page 4-128, second paragraph. The text should be expanded to address why the fluoride distribution is not as influenced by the presence of areas of unsaturated alluvium or paleochannels in more detail. This comment also applies to the chloride discussion presented on page 4-139, first full paragraph.

Response — Both fluoride and chloride distributions are influenced by the hydraulic-conductivity contrast between unconfined areas of Denver Formation and alluvial material along paleochannels. However, the effects of hydrodynamic dispersion are also more pronounced for these compounds than they are for most organic compounds. Hydrodynamic dispersion also appears to influence the distribution of those organic compounds that are relatively nonsorbing. The widespread distributions of fluoride and chloride also reflect the larger mass of these compounds introduced to the ground-water system. The text in the reference paragraph on pp. 4-128 and 4-139 has been expanded to reflect the ideas of this response.

Comment 73. — Page 4-134, last paragraph. A reference should be provided for typical background chloride levels. Background concentrations typically are less than 100,000 ug/l.

Response — Reference to background levels has been added to this paragraph.

Comment 74. — Page 4-142, second paragraph. In the UFS, the chloride plume concentrations associated with the chlorine processing plant range from

151,000 to 750,000 ug/l. The concentrations detected in confined Denver zone A are an order of magnitude larger. Possible explanations should be provided in the text.

Response — Chloride concentrations observed in the Unconfined Flow System beneath the chlorine processing building were substantially higher during the late 1950s than in recent years. Konikow (1977, p. 26) shows concentrations comparable to those shown in Figure 4.2-30 for Denver zone A. Because ground-water velocity in the Unconfined Flow System is much greater than in Denver zone A, the chloride in the shallower unit has migrated and dispersed, while chloride in Denver zone A has remained close to the source of contamination. Text has been added to clarify the source of contamination in Denver zone A.

Comment 75. General Comment. A brief discussion of the existence of and/or potential for contamination of deeper aquifers should be provided in the report. This should be supported by an evaluation of the probable maximum depth of contamination in the Denver Formation.

Response — Discussion of contamination or contamination potential in the Arapahoe and deeper aquifers would be based on virtually no data and would be highly speculative. Chapter 2.0 describes regional head gradients as generally downward from the water table to the Arapahoe and deeper aquifers. However, lateral flow predominates over vertical flow, and the potential for contamination is believed to be small. The Army will conduct an evaluation of the probable maximum depth of contamination within the Denver Formation. Additional discussion of the planned investigation, as well as the relation between the investigation and the Water RI report is provided in the response to State of Colorado general comment 1.

Comment 76. General comment. QA/QC evaluation results should be summarized in a separate section and also discussed as appropriate in the report. The section should summarize laboratory QA/QC, blank contamination, etc.

Response — The evaluation of QA/QC data is included as Subsection 4.3.3. Procedures for QA/QC are described in referenced documents. Results indicated that problems related to data reliability generally were insignificant. The subsection discusses both blanks and replicate samples.

Comment 77. Section 4.3.3. Laboratory QA/QC should also be discussed. The conclusion made in the last sentence of the last paragraph should be supported with laboratory data.

Response — Results are discussed from replicate samples used to evaluate laboratory QA/QC procedures. The results indicate that replication generally was within the range of uncertainty associated with GC/MS analyses. Anomalies are noted. The data are presented in Appendix D.7. The final sentence was in error and has been deleted.

Comment 78. Page 4-154, second paragraph. Examination of the data presented in Appendix D appears to indicate that methylene chloride was detected in

eight trip blanks and that toluene was detected in two trip blanks. Also, it does not appear that 1,1,1-TCA was detected in any trip blanks. Clarification is requested.

Response — Column heading 1,1,1-TCE used in Appendix D corresponds to 1,1,1-Tricholoroethane. Reference in the text to methylene chloride and toluene in trip blanks has been corrected.

Comment 79. Page 4-155, first paragraph. The minor anomalies noted should be described.

Response — Anomalies are noted in the second paragraph. The text has been rewritten for clarity.

Comment 80. Page 4-155, second paragraph. The wells involved, the concentrations detected, and whether these detections would have any effect on the plumes/contaminant distributions presented previously should be discussed.

Response — The purpose of these replicates was to evaluate QA/QC procedures. In general the procedures were found to be effective. The fact that sample repeatability was not possible for some sample pairs brings results from both samples into question. The effect on plume configuration is to increase uncertainty, not to alter configuration. As data are lacking for nearby wells, the QA/QC results would cause concentration contours to be dashed lines rather than solid lines.

Comment 81. Page 4-155, 4-156. The text should address whether these systematic variations were found to have any effect on the contaminant distributions and conclusions presented previously. Were the GC/MS data considered or incorporated into the previously presented contaminant distributions?

Response — Systematic variations of 20 to 50 percent between GC/MS and GC results are within the expected sensitivity of the technique. GC/MS is more effective in confirming presence of a compound than in confirming the precise concentration. Differences of the magnitude reported between GC and GC/MS effectively increase uncertainty, but do not alter presentation of contaminant distribution beyond changing solid contour lines to dashed lines.

Comment 82. Page 4-158, first paragraph. The summary noted in the second sentence of this paragraph does not appear to be in Appendix D. Clarification is requested.

Response — The text indicated incorrectly that Appendix D includes a summary. It actually includes the data listed by well number. The text has been corrected.

Comment 83. Page 4-160, first paragraph. The discussion of the distribution of non target compounds should be presented in more detail, with reference to specific figures, where appropriate. The discussion should include potential sources of a particular compound, what target compound group it is related to, and how its distribution and concentrations compare to

the distributions and concentrations of related target compounds. For example, the compound caprolactam (Figure D-174) appears to be fairly widespread in the ground water; what is the source of this compound? What target compound(s) is it related to and how do the distributions compare? The discussion should also focus on those compounds detected which are on the HSL. Data for individual wells should be discussed where appropriate.

Response — The discussion about the distribution of nontarget compounds has been expanded. Discussion includes sources, plume occurrence and wells where detections occurred. Compounds on the CERCLA Hazardous Substance List are described. Text describing caprolabtum also has been added.

Comment 84. Figures D-175 and D-187. It is not clear why these figures have been presented as these are target compounds and the text indicated that TICs which were also target compounds were not evaluated.

Response — The figures are included for completeness and compatibility with subsequent data sets in Appendix B.

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Comment 85. Page 4-1, Bottom paragraph. The text should be modified to indicate that contaminants may also enter surface water as direct discharge of contaminants or contaminated water (runoff).

Response — The text has been expanded to include this discussion.

Comment 86. Page 4-3, first paragraph. The text states that a substantial contaminant spill would contribute contaminants to the ground water by direct percolation. This statement should be expanded to also include direct percolation of contaminants from basins, sewers, and ditches as well as leakage from tanks, sumps, pits, etc.

Response — The text has been expanded to include this discussion.

Comment 87. Page 4-3, second paragraph. Infiltration of water through the vadose zone is a key mechanism for the migration of contaminants into the subsurface. It is requested that this section present or provide a better reference for all of the data, calculations and conclusions associated with the values which are presented for the effective distributed rates of recharge for the RMA, so that an evaluation of the vertical extent of soils contamination can be undertaken in a proper perspective. The narrative presents a very superficial discussion of recharge through the vadose zone. This discussion should be expanded to better address the issue of significant movement of contaminants through the vadose zone. The important factors of recharge via the unsaturated zone not discussed in this document are antecedent moisture, size of the event, and relative permeability of the soils in contaminated areas. These factors could result in a recharge wave reaching a depth unaffected by surface evaporation or the root zone.

Response — Description has been added to Section 2.0 of data, calculations, and conclusions related to distributed recharge estimates. Reference to this discussion has been made in Section 4.2. References to other studies have been improved. A worst-case analysis of contaminant migration through the vadose zone has been conducted and described in this report. The factors listed in the comment have been addressed.

Comment 88. — Page 4-6, Table 4.1. How was ground water flow into the Denver Formation estimated? This is not discussed in Appendix F. Over what season or time period do the values in the table apply? What is the confidence interval or error associated with each estimated value? Also, the value for discharge to the South Platte River is not consistent with the value presented in Appendix F.

Response — Discussion of leakage rates between the Unconfined Flow System and Denver Formation has been addressed as appropriate in Section 2.0. Reference to this section has been made in Section 4.3.1. The time period for estimates has been added to Table 4.1. All values in the table have been checked with values in Appendix F for consistency. Errors associated with estimates have been discussed as appropriate in Volume I, Section 2.0 and Appendix F, Section 2.0. A summary of errors with references has been added to Volume I, section, 4.0.

Comment 89. — Page 4-8, second paragraph. The reference provided for the numerical modeling study is inadequate and should be revised to reflect the recently issued report.

Response — The reference has been updated to include HLA (1989).

Comment 90. — Page 4-8, third paragraph. The text should indicate over what specific time period from 1987 the hydrogeologic data that were used in the model represent.

Response — The text was incorrect. The model is based on time-averaged data corresponding to the period 1981 through 1987. The text has been corrected.

Comment 91. — Page 4-8, third paragraph. Given that alluvial aquifer water levels have fluctuated up to 7 feet on a seasonal basis in many areas and have dropped tens of feet under the Basins, the statements made in this paragraph suggest that the model is not appropriate for use in the assessment of contaminant migration from either an historic perspective or from an alluvial-bedrock migration perspective.

Response — The comment is correct and essentially is a restatement of the text. The model report (HLA, 1989) includes similar qualifications.

Comment 92. — Page 4-9, second paragraph. The text implies that recharge from subcropping sandstone units of the Denver Formation is significant in the Basins area. The North-Central Study Area Report, however, states that

vertical hydraulic gradients are downward in the Basins area. Clarification is requested.

Response — The Water Remedial Investigation Report (Section 2.5) also indicates that downward gradients are typical at RMA. These gradients generally are noted in areas where sandstone strata are separated from the Unconfined Flow System by less permeable claystone. In areas where sandstone subcrops, the head in the sandstone is similar to the head in the Unconfined Flow System. As shown in Plates 1 and 2, downward flow is possible in areas where claystone separates sandstone from the Unconfined Flow System. Lateral flow is predominate in the sandstone strata. In areas of sandstone subcrop, lateral flow results in discharge from the Denver aquifer to the Unconfined Flow System. This concept of flow was described in Section 2.5 and on p. 4-7. It is consistent with the information given in the North Central SAR.

Comment 93. — Page 4-9, bottom paragraph. The text should address the impact of performing steady state modelling versus transient modelling given seasonal fluctuations in alluvial aquifer water levels and the variable pumping rates from the SACWSD water supply system wells located near the western border of the RMA. Were such factors accounted for in the sensitivity analyses? Finally, what was the model calibration acceptance criteria between actual heads and modelled heads, and how did this vary across the RMA?

Response — The model was a steady-state model. Page 4-8 indicates that it is not appropriate to use the model when evaluating transient conditions such as those identified in the comment. A steady-state model also is not appropriate for conducting sensitivity analyses of transient conditions. The text has been modified to discuss calibration criteria and spatial variations in head residuals.

Comment 94. — Page 4-10, bottom paragraph. Were any results obtained from the cross-sectional model regarding the distribution of heads between the alluvial and Denver aquifers? Between various Denver sands?

Response — The best sources of information regarding head distribution are water level measurements and corresponding potentiometric surface maps. The model was used to evaluate alternative representations of the hydraulic conductivity distribution. The alternatives were evaluated by comparison with generalized head distribution indicated from well data. As such it is not a source of information regarding head distributions.

Comment 95. — Page 4-12, second paragraph. Reference should be provided for the porosities of shale and coarse grained strata. The effective porosity of 0.4 is near the upper end of specific yield values for sands and gravels, according to McWhorter and Sunada (1977).

Response — As indicated in that text, effective porosity of 0.40 has been used successfully in models of contaminant migration at RMA. References given in the text include Konikow (1977) and Robson (1981). The value is near the upper end of expected values.

Comment 96. Page 4-12, third paragraph. Over what lateral distance does the dispersivity value of 100 ft apply? Dispersivity has been shown to be a scale-dependant phenomena.

Response Although dispersivity is scale dependent, both theoretical and applied studies in porous media have shown that scale effects decrease with distance traveled. The value of 100 ft was obtained by Konikow during transport model calibration over distances of several miles. The scale of the estimates has been included in the text.

Comment 97. Page 4-13, second paragraph. The text should indicate that contamination of the Denver aquifer can also occur through molecular diffusion of contaminants from areas of higher concentration to areas of lower concentration.

Response The text has been revised to include this discussion. However, rates of contamination by molecular diffusion are most likely negligible when compared to rates of contamination by other mechanisms.

Comment 98. Page 4-14, first paragraph. Based on the equation for particle velocity (defined as Darcy Flux in Freeze and Cherry, (1979)), the velocity is larger when the value of porosity is smaller. Therefore, contamination would travel over a larger distance during a given time period when the effective porosity is smaller compared to when it is larger. The text should be revised to reflect this. Also, reference should be provided for the porosity values.

Response Although the terms as defined in the comment misrepresent the definitions given by Freeze and Cherry (1979), the concept is correctly identified. Travel distance does increase as effective porosity decreases. However, the topic of this paragraph is not the relation between travel distance and effective porosity. The topic is the relation between sandstone interconnectivity and effective porosity.

Comment 99. Section 4.4, general comment. The section on chemical properties and effects on contaminant migration should be expanded to discuss movement of fluoride in the alluvial aquifer. A key concern is the length of time for the 10 mg/liter portion of the fluoride plume to reach the north boundary and the resulting impact on the fluoride concentrations in the effluent.

Response Discussion of fluoride migration has been added to Section 4.6 where appropriate. See comment 71.

Comment 100. Page 4-16, second paragraph. A free phase VAO plume was identified in the South Plants area by Shell. Recent (1988) Shell data should be incorporated into the report.

Response See response to comment 2.

Comment 101. Page 4-16, third paragraph. Specific gravity can affect the distribution of a dissolved contaminant. Lighter solutions tend to become distributed in the upper part of an aquifer and heavier solutions tend to sink to the bottom of an aquifer. Also, the migration of dense brines is dependant upon the concentration and solubility of the compounds in question, and not strictly upon the specific gravity. The text should be revised to include these issues.

Response The possibilities identified in the comment have been added to the text.

Comment 102. Page 4-16, last paragraph. The text should indicate how the listed factors affect solubility and how oxidation and pH conditions affect metals solubility.

Response Text has been added to indicate that solubility generally increases with increasing temperature, decreasing ionic content, decreasing pH (for metals), and increasing organic content.

Comment 103. Table 4.2. Reference should be provided for the values of specific gravity, solubility, vapor pressure, Henry's Law constant, and the Kow ranges. How Kds were calculated should also be presented. (There are many empirical equations for calculating Koc from Kow; the report needs to discuss how Koc relates to Kow, which empirical relationships were used to derive Koc values, and then how Kd relates to Koc through the organic carbon content.) Also, where a range of Kows is presented, a range of Kds should be presented. More appropriately, a range of Kds should be presented for all compounds since there are many ways to calculate Koc values from Kow values. Finally, the column on environmental fate is not always clear (for example, the terms "biodegradation, persistent" as qualifiers appear to contradict one another.

Response Values shown in Table 4.2 are referenced and discussed in Appendix E. Calculation of partition coefficients also is described in Appendix E. Appropriate references to Appendix E has been placed in the text of Section 4.4. The final column of Table 4.2 has been clarified.

Comment 104. Page 4-22, last paragraph. The retardation factor presented for TCE on Table 4.2 is extremely high. The lower values derived from the site specific field testing are much more appropriate and are more in line with values presented in the literature.

Response Text has been added indicating that the values between 1.0 and 1.8 are similar to values obtained in other studies. The values given in Table 4.2 are based on estimates for soil.

Comment 105. Pages 4-23 to 4-25. In the discussion for each compound group, the qualifiers low, moderate, and high should be referenced to actual values from the table. Also, fate properties and mobilities should be briefly related to observed contaminant distributions in ground water.

Response — References have been added where appropriate. Fate of contaminants has been discussed in the revised text for contaminants where effects of transformation or degradation are observed. Efforts to relate mobility of contaminants, as indicated by Kd or R values in Table 4.2, to observed contaminant distribution have not been successful. Generally observed distribution is more widespread than would be expected on the basis of data in Table 4.2. Causes for these differences may be due to errors in estimating organic matter in the aquifer material, effects of multiple-species adsorption, adsorption to colloids that are relatively nonreactive and migrate with ground water, or consolvency. Quantitative efforts to resolve differences between expected and observed differences have not been undertaken as part of the investigation of the nature and extent of contaminants that is central to the Water Remedial Investigation Report. If an understanding of enhanced migration is needed during Feasibility Studies, the mechanisms will be investigated as part of a Feasibility Study.

Comment 106. Page 4-23, third paragraph. Please expand on the effects of cosolvency on Kd or R values. Would cosolvent effects reduce the effective Kd's for OCP's to those of the VHO's?

Response — Data to address this question are not available. See response to comment 105.

Comment 107. Page 4-25, top of page. It is not clear which compound group is being discussed.

Response — Text has been added to indicate the discussion is about volatile aromatic organics.

Comment 108. Page 4-25, third paragraph. Please indicate whether mercury was introduced into RMA soils and basins as a solid or a liquid.

Response — Text has been added to indicate that mercury was introduced at RMA in elemental form and as mercuric compounds.

Comment 109. Page 4-26, first paragraph. The second sentence should be qualified. Dieldrin, which is strongly sorbed, has undergone extensive migration. The final sentence should also indicate that adsorption is also directly related to the organic carbon content of the solid phase, and should briefly discuss the relationship amongst adsorption, Kow and organic carbon.

Response — The second sentence has been qualified. Reference to Appendix E has been added to provide greater detail.

Comment 110. Page 4-26, second paragraph. The Army should indicate if and where volatilization processes have been observed or suspected to occur on the RMA.

Response — Text has been revised to describe volatilization and specific conditions at RMA in Section 4.4.

Comment 111. Page 4-26, third paragraph. Although transformation and degradation generally result in daughter products which are less hazardous, the text should indicate that there are notable exceptions to this. These include degradation of trichloroethylene to vinyl chloride, trichloroethane to dichloroethylene, hydrazide to NDMA, aldrin to dieldrin, and DIMP to IMPA. The Army should indicate where they are seeing transformation and/or degradation processes, and what daughter products are being observed.

Response The text recognized that notable exceptions occur. Exceptions were identified in Table 4.2. Degradation of contaminants listed in the comment has been added to Section 4.4.

Comment 112. Page 4-26, third paragraph. The final sentence is incorrect for most VHO compounds, which degrade at faster rates under anaerobic conditions. Also, how do the degradation rates depend on the listed characteristics?

Response The sentence has been modified. Degradation of most volatile halogenated organics has been identified in the text as an exception. Appendix E has been referenced for additional description of transformation and degradation processes.

Comment 113. Table 4-3. Additional discussion should be provided in each specific source area pathway section on the site-specific mechanisms shown on this table by which contaminants may have been introduced to the ground water. The general mechanisms presented on Page 4-3 should also be incorporated into each discussion. For example, where contaminants are believed to have entered the ground water via an improperly constructed well, reference to specific wells and their location with respect to specific sources should be made. Also, it would appear that there should be an additional category for leakage from the basins.

Response The purpose of the Water Remedial Investigation Report is to provide a general description of contaminant distribution and mechanisms for migration. Site-specific discussions are more appropriately included in reports that describe conditions in specific areas. Leakage from basins is equivalent to vertical migration of contaminants via conducive geologic conditions.

Comment 114. Page 4-35, fourth paragraph. It is not clear where the sporadic occurrences of VOCs referred to in the text occur in the areas mentioned. The 04030 well nest located near the Motor Pool, for example, has consistently shown high concentrations of TCE. Clarification is requested.

Response The text has been changed to indicate that volatile organic compounds have been detected at several locations within the Railyard and Motor Pool areas.

Comment 115. Page 4-36 first paragraph. Please provide reference to support the statement that the DBCP plume is completely captured by the ICS.

Response — Although detected upgradient of the ICS, the contaminant has not been detected downgradient of the ICS in recent years. Samples of inflow and outflow water at the ICS indicate the system is performing as designed.

Comment 116. Page 4-38, second paragraph. The text should specify if the water held in Basin C was clean of wastewater.

Response — The text has been clarified to indicate periods when Basin C held fresh water and periods when Basin C held waste water.

Comment 117. Page 4-39, Section 4.6. The travel time calculations should include in the discussion each of the variables that are used. Hydraulic gradients are consistently missing. Also, references should be provided for the porosity values that are presented.

Response — References have been provided for estimates of hydraulic gradients and hydraulic conductivity. As stated in the text, values of effective porosity initially are assumed. However, subsequent comparison with observed migration distance serves to confirm initial estimates.

Comment 118. Page 4-40, third paragraph. The estimates should be related to observed contaminant distributions along this pathway.

Response — Uncertainty regarding the location and time of initial contamination along this pathway precludes meaningful comparisons.

Comment 119. Section 4.6, general comment. Similar evaluations should have been performed for retarded compounds using retarded rates of transport.

Response — See response to comment 105.

Comment 120. Appendix E. This appendix is not referenced in the text. The information presented in this appendix should be referenced as appropriate in the text or the appendix should not be included. The last sentence in the second paragraph on page E-6 is incorrect.

Response — Appendix E has been referenced in Section 4.4. The sentence on p. E-G has been corrected to indicate division rather than multiplication.

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Edward J. McGrath

May 1, 1989

Mr. Donald L. Campbell
Office of the Program Manager
Rocky Mountain Arsenal, Building 111
ATTN: AMXRM-PM
Commerce City, CO 80022-2180

Re: United States v. Shell Oil

Dear Don:

Enclosed please find Shell Oil Company comments on the Draft Final Remedial Investigation Reports for the South Plants, North Plants, and Central study areas (Version 2.1, March 1989); and the Draft Final Water Remedial Investigation Report (Version 2.2, March 1989).

A large portion of Shell's comments derive from the tendency of the SARs to use assumptions and draw conclusions that are not warranted by the data. This arises primarily in the attempt to describe the nature and extent of contamination at individual sites even when too few data points are available for such characterization. This tendency is compounded by the Army's preoccupation with calculating of estimated volumes of potentially contaminated soil on a site by site basis, despite Shell's repeated comments that such estimates have practically no value (i.e. without EA input) in development of the ROD. Shell believes that the SARs satisfactorily summarize contamination on the RMA. However, the SARs do not provide the degree of resolution which ultimately may be required for actual remediation. As has been recognized from the beginning and allowed for in FS Technical Plans, the need for additional data will be indicated during the course of FS work. This will result in a focused, efficient program for collecting the level of detailed data required for the ROD.

Since the Study Area Reports are summaries of the RI data, the SARs should be used only for general, qualitative purposes. The Army should state in each SAR that the intent of the data presentations is to provide a general overview of the extent and nature of contamination in each study area, and that for work performed in the Feasibility Study, the primary source of data

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on contaminant distribution will be the USATHAMA database and the Contamination Assessment Reports.

Shell's comments on each report address general features as well as specific sections of the text, tables, figures, and plates. As you will notice, some of the comments are similar for many or all of the SARs because of the consistent nature of the background information and analytical approaches that were used. We have included these comments in each SAR for the convenience of the individual SAR authors.

Our specific concerns regarding these documents are as follows:

1. The approach of grouping analytes and summing concentrations of individual compounds within analyte groups reduces the usefulness of the RI data for the EA and FS, which will evaluate compounds individually. This needs to be emphasized in each SAR.

2. We suggest that the soil volume calculations, contaminant distribution maps, extent of potential soil contamination maps, and associated text be revised to reflect the actual depth of soil sampling (i.e., 0-1, 4-5, 9-10 ft., etc., rather than 0-2, 2-5, 5-20, and >20ft).

3. The assumptions made for estimating volumes of contaminated soil lead to unreliable estimates of these volumes and, therefore, limit the usefulness of the calculations in selection of remedial technologies.

4. The importance of the complexities and heterogeneities of the water-bearing zones should be described clearly.

5. Presentation of the distribution of groundwater contaminants using maximum concentrations of analytes from multiple sampling events ignores temporal trends and may not be representative of actual contaminant distribution. Inaccurate plume configurations and contaminant flux calculations may result from this practice.

6. Calculations of contaminant flux are conservative to the point of being inaccurate and do not reflect the limited accuracy that is inherent in the calculations.

7. We believe that the RI and historical databases contain sufficient information to describe and evaluate contamination in the alluvial and Denver Formation water-bearing zones. However, in some cases the data have not been analytically evaluated, and in other

cases, conclusions are drawn that are not supported by the data.

These items are addressed in detail in the attached comments for each document. Please let me know if you have questions.

With best regards.

Sincerely yours,

Nea Brown for

Edward J. McGrath

EJM/rw

Enc.

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RESPONSES TO SPECIFIC CONCERNS IN COVER LETTER
TRANSMITTING SHELL COMMENTS ON
NORTH PLANTS, SOUTH PLANTS, CENTRAL STUDY AREA (VERSION 2.1)
AND WATER REMEDIAL INVESTIGATION REPORTS (VERSION 2.2) - MARCH 1989

Comment 1. The approach of grouping analytes and summing concentrations of individual compounds within analyte groups reduces the usefulness of the RI data for the EA and FS, which will evaluate compounds individually. This needs to be emphasized in each SAR.

Response The SARs were never intended to reiterate all of the raw data collected during the course of the Remedial Investigation. Rather, they were designed to integrate and summarize these data. This summarization process does not reduce "the usefulness of the RI data for the AWAY and FS," since the full data set is available to and is being used by the AWAY and FS groups. The SARs (and the media reports) are used by these groups to focus their efforts on the most serious contamination problems. Nevertheless, a sentence has been inserted into Section 2.0 of the South Plants, North Plants, Central and North Central Study Area Reports to reflect Shell's concerns.

Comment 2. We suggest that the soil volume calculations, contaminant distribution maps, extent of potential soil contamination maps, and associated text be revised to reflect the actual depth of soil sampling (i.e., 0-1, 4-5, 9-10 ft., etc., rather than 0-2, 2-5, 5-20, and >20 ft).

Response The standard sampling intervals are noted in the final report. Technical plans written for soil sample collection tasks specified these intervals for design and planning. The analytical results have already been presented for each sampled interval of each soil boring in the tables and figures of the Contamination Assessment Reports (CARs) and Phase II Addenda. These data were compiled into four standard depth intervals (0-2 ft, 2-5 ft, 5-20 ft, and >20 ft) for all distribution maps in all the Study Area Reports (SARs). The intervals were chosen to complement current and future efforts envisioned by the Feasibility Study and the Endangerment Assessment. Organizing the data into these four intervals enabled general conclusions to be drawn concerning not only the soil media, but also surface water, ground water, structures, air, and biota while serving as useful information sources for companion efforts scheduled under the Technical Plan for RMA.

Maps will not be prepared in these summary documents for each standard sampling interval, nor will volume calculations be redone, nor text revised to specific sampling intervals, as the SARs are designed to summarize the results of the remedial investigations and not to recapitulate the detailed information previously presented in the CARs and Phase II Data Addenda. The AWAY and FS will utilize the detailed information available in these reports and in the RMA computerized database.

Comment 3. The assumptions made for estimating volumes of contaminated soil lead to unreliable estimates of these volumes and, therefore, limit the usefulness of the calculations in selection of remedial technologies.

Response — The soil volume estimates presented in the SARs help fulfill the objectives of the Remedial Investigation (Remedial Investigation) to define the nature and extent of potential contamination at RMA, and to aid in the development of candidate remedial alternatives. The selection of remedial alternatives and technologies as part of the Feasibility Study will depend on action levels, as yet undetermined. Detailed soil volume estimates based on these specifics will be calculated as part of the Feasibility Study effort. The volume estimates presented in the SARs are based on clear, explicit assumptions. Their reliability depends on their application. It is not within the scope of the SARs to generate soil volume estimates incorporating all factors necessary to select a remedial alternative and technology.

Comment 4. — The importance of the complexities and heterogeneities of the water-bearing zones should be described clearly.

Response — The Army recognizes that the complex and heterogeneous nature of the aquifer materials in places within various water-bearing zones at RMA can act either to facilitate or to hinder ground-water movement and potential contaminant migration. Such complexity necessitates the use of reasonable approximations of aquifer properties, based on the interpretation of data from a variety of sources, when evaluating potential contaminant migration and/or calculating volume of flux estimates.

Comment 5. — Presentation of the distribution of ground-water contaminants using maximum concentrations of analytes from multiple sampling events ignores temporal trends and may not be representative of actual contaminant distribution. Inaccurate plume configurations and contaminant flux calculations may result from this practice.

Response — Given the requirements of the Remedial Investigation, the inherent limitations imposed by the nature of environmental data collection in the real world, the wide range of previous investigative efforts at RMA, the often voluminous quantity of data collected during those investigations, and the sometimes competing interests of all the parties to report as comprehensive, thorough, and specific a remedial investigation as possible, the Army believes that the data presentation methods selected for each study area are reasonable, responsible, sufficient, and adequate to characterize the nature and extent of the potential contamination conditions present at RMA. Where possible, data from the most recent and thorough sampling effort conducted under the Remedial Investigation were used to map potential ground-water contaminant distributions. Not all study areas had ground-water data sets from a single recent sampling event (ground-water samples were collected quarterly) sufficient to fully characterize the conditions within that study area. Where the frequency of detections was low, or where detections were sporadic or not repeated from one sampling event to the next, the historical data and data from other sampling events were compiled to produce distribution maps, and highest detections were plotted. Where a review of historical data, within the limitations imposed by changing and increasingly sensitive

detection limits and certified reporting limits (CRLs), indicated that distributions had remained relatively stable or similar over time, more comprehensive data sets spanning several sampling episodes were compiled and averaged utilizing accepted practices for environmental data to generate distribution plots and plume configurations. Temporal trends were not ignored, but were deemphasized when such trends were deemed insignificant or absent.

Comment 6. Calculations of contaminant flux are conservative to the point of being inaccurate and do not reflect the limited accuracy that is inherent in the calculations.

Response The calculations are adequate to define the nature and extent of potential contaminants for the purposes of these summary reports. Contaminant flux calculations are conservative; however, the underlying assumptions used to generate the flux estimates are clearly described in the relevant section of the final report. It is agreed that, based on these assumptions, unwarranted quantitative significance should not be attached to the calculations.

Comment 7. We believe that the RI and historical databases contain sufficient information to describe and evaluate contamination in the alluvial and Denver Formation water-bearing zones. However, in some cases the data have not been analytically evaluated, and in other cases, conclusions are drawn that are not supported by the data.

Response The SARs summarize the available data regarding potential contamination at RMA and draw conclusions based on the data where appropriate and justified. We agree that the Remedial Investigation and historical databases contain sufficient information to describe and evaluate potential contamination in the alluvial and Denver Formation water-bearing zones. Where conclusions are necessarily speculative, they are clearly identified as such, and every attempt has been made to base them on reasonable evaluations and interpretations of data from other areas or regions with similar conditions.

SHELL OIL COMPANY COMMENTS
DRAFT FINAL WATER REMEDIAL INVESTIGATION REPORT
VOLUME I (MARCH 1989)

GENERAL COMMENTS

Comment 1. Throughout this report, the impression is given that more is known about the aquifer than truly is known. The importance of the complexities and heterogeneity of the aquifer appears to be minimized. Uncertainty in understanding of the aquifer is not adequately acknowledged. For example, rather than saying that "estimates of hydraulic conductivity range from . . .," the report says that "hydraulic conductivity ranges from . . . ." Another example is that when travel time estimates from the model are given, the only allowance for parameter variability or uncertainty used in determining the range of the estimates is the effective porosity. In reality, the porosity is more accurately estimated than some of the other parameters relating to transport such as hydraulic conductivity, and sometimes even the hydraulic gradient. The text implies that travel times can be estimated with a degree of certainty by using the model. We disagree with this conclusion.

Response Although parameter uncertainty is never completely eliminated in hydrogeologic investigations, efforts at RMA have reduced uncertainty substantially. Understanding of the flow system is particularly good in the alluvial and eolian hydrogeologic units. In general, the Remedial Investigation has described the flow system at RMA sufficiently to begin feasibility studies. Nevertheless, uncertainty does exist at RMA and generally is identified in the text. Exceptions to this generality occurred in the previous version of the report and have been corrected in the new version. In addition to editorial changes such as the one suggested in the comment, several technical changes have been made. For example, errors associated with recharge and discharge estimates have been discussed. Travel time estimates have been based on ranges of estimates for hydraulic conductivity as well as on ranges of effective porosity.

Comment 2. The HLA model of RMA was utilized beyond the limitations of its assumptions and data reliability. Estimating travel times in heterogeneous aquifers with information that was incorporated in the model is questionable. For example, travel times in the Basin A-Basin A Neck were estimated, yet the aquifer permeabilities reported as being used in the model do not match aquifer test results from wells in this location. Considering the data limitations, transient effects over history that are not considered in the model, poor calibration in some of the important areas (notably the areas generally encompassed from Basin A through Basin F and on to the North Boundary), and the fact that the bedrock hydraulic conductivity was a factor of 10 greater than the geometric mean of aquifer tests in the permeable portions of the Denver Formation, the text incorrectly conveys the impression of greater reliability in the model results than is warranted. This is especially true with regard to contaminant transport as demonstrated by the fact that use of a retardation factor of 1.6 for TCE more closely matches the observed

migration than does the use of the literature value of 11. There are many sources of error in transport modeling. The implication that the error can be accounted for merely by adjusting the retardation factor is inappropriate. A much more accurate conclusion is that there are many sources of error in the model and model parameters that collectively result in a fairly significant discrepancy between the observed travel time of TCE and the predicted travel time. The unjustified confidence in the model and its predictions/results is common in the report.

Response

Travel time calculations based on model-derived estimates of hydraulic conductivity have been reevaluated to include a range of estimates obtained from aquifer tests. The HLA model will not form a basis for travel time calculations. The fact that the observed distribution of TCE is consistent with an estimated retardation factor of 1.6 rather than a soil literature value of 11 does not bring into question the value of 1.6. As indicated in the text, multiple well tracer tests at RMA also indicate that an estimate less than 1.8 is reasonable. The soil literature value is more appropriately questioned.

Comments regarding accuracy and reliability of the HLA model are not entirely correct. Aquifer-test results obtained by MKE in the Basin A Neck effectively bracket the estimate of hydraulic conductivity in the HLA model. The model was developed to simulate recent study-state conditions. The hydraulic-conductivity estimate in the model for unconfined parts of the Denver Formation is an order of magnitude greater than estimates obtained from slug tests in confined sandstone of the Denver Formation. However, the comparison with aquifer-test results in unconfined parts of the Denver Formation is good. For purposes of Remedial Investigation the model is sufficiently reliable. More refined modeling may be done for other purposes.

Comment 3.

In Shell comments on the Draft Final Study Area Reports, we noted that the Draft Final Water RI described the alluvial and uppermost Denver Formation water-bearing zones together as the Unconfined Flow System, while deeper, confined water-bearing zones within the Denver Formation were described together as the Confined Flow System. To facilitate cross-referencing between the SARs and the Water RI, we suggested that the SARs use the same terminology and conceptual model as the Water RI.

However, those comments were based on the assumption that the large contrasts in hydraulic conductivity and the dynamics of flow between the alluvial and uppermost Denver Formation water-bearing zones would be fully qualified and described, and that the anisotropic and heterogeneous nature of the Unconfined Flow System would be explicitly stated in both the Water RI and SARs. Since these qualifications have not been convincingly incorporated into the descriptions of the Unconfined Flow System, we are concerned that combining the alluvial and uppermost Denver Formation water-bearing zones may be misleading and result in conceptual errors in interpretation and preliminary remedial alternatives.

Without thorough qualification of the differences between the alluvial and uppermost Denver Formation water-bearing zones within the Unconfined Flow System, it is made to appear that flow occurs in the same volume and rate through the uppermost Denver Formation as the alluvium. This conceptual model is not correct.

We are also concerned that the terminology "Unconfined Flow System" is not completely accurate. In some areas (e.g., the South Plants mound), water in the uppermost water-bearing zone within the Denver Formation may be under confined or semi-confined conditions. This condition is not reflected by the term "Unconfined Flow System."

We believe that while the SARs and the Water RI should be consistent, the terminology and conceptual model for the Unconfined Flow System should be evaluated in light of the above concerns, and either explicitly qualify the limitations of the conceptual model or reorganize the descriptions of the system appropriately (e.g., redefine as the "uppermost flow system"). Please also coordinate a standard terminology and conceptual model for the Water RI and the SARs so that the documents can be easily cross-referenced.

Response

Evidence is not available of anisotropy in hydraulic conductivity estimates of the Unconfined Flow System. The heterogeneous nature of the Unconfined Flow System, particularly the large differences between aquifer characteristics of alluvium and unconfined parts of the Denver Formation, is repeatedly stated in Sections 2 and 4 of Volume I and Section 2 of Volume III. Statements are not made in the report to the effect that volume and rate of flow in alluvium and unconfined parts of the Denver Formation are the same. The text states repeatedly that volume and rate of flow in the unconfined parts of the Denver Formation are less than in alluvium.

Shell's concern that the aquifer system terminology may not be completely accurate is shared by the Army. As Shell has pointed out in previous comments, uncertainty is unavoidable in hydrogeology. The aquifer classification used in this report represents a reasonable operating hypothesis based on current understanding. As understanding of contaminant migration in the Denver Formation improves, it is possible that the classification will need revision.

Comment 4.

To be consistent with the Study Area Reports and facilitate cross-referencing, we suggest that the analyte groups utilized in this report be consistent with those in the SARs and the order in which the analyte groups are presented and discussed in the Water RI be consistent with the SARs. For example, chlorobenzene is grouped with volatile aromatic organic compounds in this text, but is grouped with volatile halogenated organic compounds in the SARs.

Response

The focus of the SARs is to present information on the extent and mass of contaminants. Although the Water Remedial Investigation Report provides a general overview of the nature and extent of contamination, the report also describes mechanisms of contaminant migration and

alteration. To facilitate the latter, the Water Remedial Investigation places additional emphasis on the occurrence of individual analytes. This has resulted in presentation differences between the reports. Although chlorobenzene is grouped with volatile aromatic organics in this report, it also is included in a separate discussion and maps. Within the constraints imposed by differing purposes, the order of presentation in both types of report is the same.

Comment 5. Since the Water RI is a summary of the RI water data, it should be used only for general, qualitative purposes. We believe that a qualifier should be included indicating that the intent of the data presentations is to provide a general overview of the extent and nature of surface water and ground-water contamination, and that for work performed in the Feasibility Study, the primary source of data on contaminant distribution should be the USATHAMA database.

Response A qualifier has been added to indicate that the purpose of the report is to provide a general overview of contamination in water at RMA. The Water Remedial Investigation Report is not intended to be the only source of data for the Feasibility Study. Study Area Reports, the USATHAMA database, and other detailed investigations also are appropriate sources of this information.

SPECIFIC COMMENTS

Page S-1, second paragraph

Comment 1. Some mention should be made of the boundary systems and their effectiveness in eliminating (or at least reducing) the threat to downgradient wells.

Response Text has been added to indicate that containment systems have been installed in three primary flow paths to reduce contaminant migration to off-post areas.

Page S-1, last paragraph, fifth sentence

Comment 2. The Denver Formation is not composed predominantly of sandstone and siltstone. Low permeability claystone and shale are predominant and sandstone and siltstone lenses are secondary materials.

Response The sentence does not indicate that sandstone predominates. It indicates that the lenticular sandstone tends to occur in thick sequences of shale and claystone. This implies that shale and claystone are predominant. However, the sand-shale ratio does approach 1.0 in local areas.

Page S-2, second paragraph

Comment 3. The citation of irrigation as a recharge mechanism for the Unconfined Flow System is not relevant on-post, although recharge via irrigation is

pertinent to the drainage outside the RMA boundary. All references to irrigation should clarify whether they are on-post or off-post.

Response The qualifier, off-post, has been added to the text.

Page S-2, second paragraph, seventh sentence

Comment 4. The references to Basin C in the report are inconsistent. Please clarify in this and all other appropriate references that it was used from 1953 to 1956 to store liquid waste and in 1967 and 1969 through 1975 to store fresh water. Please check the dates for all further references.

Response References to Basin C have been reviewed for consistency. Text has been revised to indicate the following: Basin C held water during 1957 and 1958, again in 1966 and 1967, and a third time during the consecutive years beginning in 1969 and ending in 1974. Liquid wastes were transferred from Basin F to Basin C on one occasion only in the spring of 1957 and were retained in Basin C for a period of approximately 30 days while the liner in Basin F was repaired. The liner was damaged due to wind-induced wave action.

Page S-2, third paragraph, second sentence

Comment 5. We are not aware of any successfully completed water balance calculations that have been made on Basins A through F or Lake Mary. We are aware of water balance calculations that were attempted for Basin A and Basin F, but measurement errors appeared to dominate the calculations.

Response Water balance calculations presented in Appendix F and summarized in Section 2.0 of Volume I are initial estimates, subject to refinements. Errors for these estimates are large. Text qualifying the estimates has been added in all appropriate report sections.

Page S-3, third paragraph

Comment 6. Discussions of vertical ground-water movement should emphasize the fact that although the regional picture indicates the potential for downward movement, the major flow volume and direction are locally controlled by lateral flow through the Unconfined Flow System. Vertical movement should not be over-emphasized because this may be misleading. Please qualify all further discussions regarding vertical flow.

Response The comment is correct in implying that vertical movement is not well understood at RMA. Nevertheless evidence of vertical movement is quite strong. Without vertical movement, contamination of the Denver aquifer would not be nearly as extensive as it is. Throughout the text it is clear that the majority of flow occurs in the Unconfined Flow System and that the shallow system influences conditions in the deeper system. At the same time, flow in the deeper system cannot be ignored. This paragraph qualified discussion of flow in the Denver aquifer by indicating that the distribution of hydraulic conductivity "probably" restricts vertical flow.

Estimates of hydraulic interchange between the two systems are considered to be "initial" estimates.

Page S-3, third paragraph, last sentence

Comment 7. Does the value of 600 acre-ft/yr (372 gpm) represent Denver Formation discharge within the RMA boundaries or over the entire model area?

Response The study area for the model is defined on page 1-2. Because it is not defined in the executive summary, a definition has been added.

Page S-4, fifth paragraph and following

Comment 8. References to peak concentrations does not give the reader any notion at all of what typical concentrations are found in Arsenal ground water.

Response Designers of remedial action need to know peak concentration, mass-averaged concentration, velocity-averaged concentration and other characteristics of plumes. For purposes of evaluating public health and safety, peak concentrations are particularly important. For this reason the summary includes peak concentrations. Designers will read more than the summary.

Page S-5, second paragraph

Comment 9. The distribution of mercury in ground water has been omitted from this report. Please either include a discussion or justify the omission.

Response Text has been modified to indicate that areally extensive compounds are discussed. Mercury was rarely detected. Maps of mercury distribution in ground water are presented in study area reports.

Page S-7, second paragraph

Comment 10. The assumed effective porosity of 0.40 is unrealistically high and suggests that the other assumed values used in modeling are unsuitable. The estimates of travel time ranges could be in error by a factor of 5. We question whether the ranges presented are meaningful and realistic.

The focus on "effective porosity" underscores the fact that numerous other parameters are equally important in determining contaminant migration flow rates. Please define "effective porosity" clearly and justify why it is the preferred parameter. Please edit all references to effective porosity in the text accordingly.

Response The value of 0.40 is consistent with values used effectively in calibrating transport models of RMA (e.g., Konikow, 1977). The value of 0.40 is at the upper end of likely values but it is not unrealistic. Estimates of travel time will be reevaluated (see general comment 2). The definition of effective porosity is a standard one used in general textbooks of hydrogeology. It is a constant of proportionality that linearly relates Darcian velocity and average linear velocity. It is related to but not the

same as bulk porosity. Because it is a standard definition, it has not been included in the text. A more rigorous definition of the term can be found in U.S. Geological Survey Water Supply Paper 1988. There are no technically correct alternatives to effective porosity. Consequently edits are not needed.

Page S-7, third paragraph, fourth sentence

Comment 11. It should be mentioned that the alluvium beneath Basins C, D, E, and F is largely unsaturated. Contaminants may be virtually stagnant, existing at or just below the bedrock surface. Please present a range of thicknesses for saturated thicknesses along the Basin F pathway.

Response Rates of movement in the Unconfined Flow System from Basin F toward the north boundary are slow. Movement occurs in both alluvial sediments, where saturated, and shallow parts of the Denver Formation. As indicated in the text, historical rates of movement were more rapid as a result of steeper gradients and greater degree of saturation of alluvium. But water is not stagnant. The range of thickness is indicated to be less than 10 feet.

Page S-7, third paragraph, last sentence

Comment 12. According to our calculations (based on recent drilling), the flowrate just north of Basin F is probably about 1 gpm. Presently, there is negligible recharge from Basin C. The average recharge rate from Basin C during the years 1969 through 1975 is estimated to be about 449 gpm (1 cfs). During peak periods of usage, the recharge rate could have exceeded 4000 gpm. It is our belief that travel times affected by the flooding of Basin C were probably at least two orders of magnitude shorter than they are now.

Response The referenced flow rate (1 gpm) is for water in saturated alluvium and ignores flow in unconfined parts of the Denver Formation. Estimates of historical recharge beneath Basin C are subject to substantial uncertainty. Analysis of recharge using a water budget model resulted in no degrees of freedom to evaluate model reliability. Ground-water model analysis by Konikow (1977) tends to confirm the estimate of 450 gpm. However, parameter estimates obtained with this model also are subject to substantial uncertainty. The belief that travel time was two orders of magnitude greater when Basin C was flooded is not appropriately conservative, given the large uncertainty in recharge estimates and the lack of consideration of flow in the upper Denver aquifer.

SECTION 1.0: INTRODUCTION

Page 1-1, first paragraph, second sentence (and Volume III, page 1-1)

Comment 13. Change ". . . Compensation and Liability Act (CERCLA), the Superfund Amendments and Reauthorization Act (SARA), . . ." to ". . . Compensation

and Liability Act, as amended by the Superfund Amendments and Reauthorization Act (SARA), . . ."

Response The suggested change has been made.

Page 1-3, Military History

Comment 14. Please clarify here, and in other appropriate sections, that DDT was formulated for the Army and utilized by the Army for pest control on-post.

Response Although the Army used DDT on-post, it is inappropriate to imply that DDT was manufactured solely for Army use.

Page 1-3, fourth paragraph (and Volume III, page 1-4)

Comment 15. The second sentence does not distinguish between chemicals manufactured by CF&I and Julius Hyman & Company (note the ampersand). Separate sentences for CF&I and Hyman would avoid such confusion. Shell Chemical Corporation acquired Hyman in 1952, but did not replace Hyman as lessee until after Hyman was merged into Shell Chemical Corporation in 1954. The references in the text to Shell Chemical Company should be changed to Shell Chemical Corporation.

Response Suggested changes have been made.

Page 1-4, first paragraph

Comment 16. Change "Shell and the Army" to "Shell and/or the Army," to reflect more accurately the Federal Facility Agreement.

Response Suggested change has been made.

Page 1-4, second paragraph, last sentence

Comment 17. Delete ". . . in accordance with operational and regulatory requirements."

Response Suggested change has been made.

Page 1-5, first paragraph

Comment 18. Please insert "(prior to 1957)" after "unlined" and "(after 1957)" after "lined."

Response Suggested change has been made.

Page 1-6

Comment 19. Please include this study in the list of studies:

U.S. Army Corps of Engineers, Omaha District, Program for Reclamation

of Surface Aquifer, Rocky Mountain Arsenal, Denver, Colorado, January 1961.

Response — The list of studies includes those considered significant in defining the hydrogeologic system and identifying toxic constituents. Although important, the referenced report does not meet these criteria.

SECTION 2.0: ENVIRONMENTAL SETTING

Page 2-1, third paragraph, fifth sentence

Comment 20. According to Linsley, Kohler, and Paulhus ("Hydrology for Engineers", McGraw-Hill Book Company, 1975) ". . . there is good reason to consider potential evapotranspiration to be equivalent to the evaporation from a free-water surface of extended proportions but with negligible heat-storage capacity." Under this definition the potential evapotranspiration on RMA is much higher than 24 to 30 inches. Pan evaporation at Cherry Creek Reservoir averaged over 53 inches per year from 1968 through 1984. Even after applying a realistic pan coefficient, the resulting estimate of free-water evaporation is significantly higher than 24 to 30 inches. Estimates of shallow lake evaporation in the Denver area are generally around 40 inches per year. If another meaning is intended by the term "combined potential evaporation and transpiration" it should be set forth in the text.

Response — The statement in the text was incorrect. The text has been changed to agree with Appendix F, p. 2-1 and will indicate annual potential evaporation is 38.5 inches.

Page 2-2, first paragraph

Comment 21. It would be appropriate to include an explanation of how mean monthly discharge in First Creek can drop from 69.3 acre-ft/month at the RMA boundary to 24.7 acre-ft/month near the mouth when the Executive Summary (page S-2) states that during periods of negligible streamflow (which are common), First Creek north of the RMA boundary gains ground water at a small rate.

Response — The two statements are not inconsistent. When flow is negligible, First Creek gains water. However, when flow is larger, stream-aquifer relations and head differences result in a net loss of water along First Creek. Stream-aquifer relations are discussed on p. 2-16.

Page 2-2, second paragraph, third and fourth sentences

Comment 22. The Havana and Peoria Interceptors have not been known to deliver water from south of RMA to any of the four lakes. This would happen only if stored water in the Havana Pond was released into the Sand Creek Lateral or if the pond overtopped. Shell is not aware of such events ever having occurred.

Response — The sentence has been changed to indicate that the various interceptors and canals deliver water to lakes and impoundments. Water stored in Havana Pond occasionally has been released to Sand Creek Lateral, most recently on May 18, 1988.

Page 2-2, third paragraph, fifth sentence

Comment 23. — The Rod and Gun Club Pond does not receive its water directly from an interceptor channel, as implied. Water from the interceptors would need to fill Lower Derby Lake first, then flow through the overflow ditch into the pond.

Response — The text has been changed as suggested.

Page 2-3, Table 2.1

Comment 24. — The time periods during which the streamflow statistics were collected should be stated. Also, a map should be included showing the location of the gaging stations.

Response — Time periods have been indicated. Reference to Figure 2.3-2 has been added.

Page 2-4, first line

Comment 25. — Following completion of the Basin F IRA, Basin F no longer has any water storage capacity. Because Basin F no longer exists, all references should be in the past tense.

Response — The text has been changed as suggested.

Page 2-9, second paragraph, fourth sentence and page 2-10, second paragraph, first line

Comment 26. — In areas where the Unconfined Flow System is primarily alluvium, hydraulic gradients less than 0.002 and greater than 0.009 ft/ft exist over fairly large and important areas. For example, the gradient in most of Section 23 is much less than 0.002 ft/ft and the gradient through most of the Basin A Neck is greater than 0.009 ft/ft.

Response — Both areas identified as exceptions to the statement on page 2-9 are areas where the Unconfined Flow System consists of alluvium and/or Denver Formation. Nevertheless, hydraulic gradients have been reevaluated and the text has been changed to indicate a range of 0.0001 to 0.01. The smaller value was obtained in section 23. The previous value of 0.002 was a typographical error.

Page 2-10, second paragraph

Comment 27. — The alluvial ground-water gradient between Basin F and the RMA northern boundary is low because the volume of flow is very low and the aquifer has a very high hydraulic conductivity. The gradient would be low regardless of the presence of the North Boundary System.

Response — The comment and paragraph are in general agreement. Both indicate that volumetric flow rate is low. Both indicate that hydraulic conductivity of alluvium is large, where saturated. The largest area of saturated alluvium is near First Creek, where substantial quantities of water mix with water flowing from Basin F. The combination of these factors controls the gradient. Throughout much of the area north of Basin F, the water table is at or below the bedrock contact. In these areas hydraulic conductivity is low. The text has been modified to indicate that the North Boundary Containment System influences, but does not control, the gradient.

Page 2-12, first paragraph

Comment 28. Please clarify that Table 2.3 also lists recharge areas located outside the RMA boundary.

Response — The text indicates that recharge rates are for the study area. The study area was defined previously on p. 1-2. The table also indicates that estimates apply to the study area.

Page 2-12, second paragraph, first sentence

Comment 29. Discharge from the Unconfined Flow System also occurs as seepage to First Creek as stated on page S-2.

Response — Text has been modified as suggested.

Page 2-12, second paragraph, fifth sentence

Comment 30. Were water budget calculations made for the Rod and Gun Club Pond? They are not shown on Table 2.3-4 in Appendix F.

Response — Water budget calculations for the Rod and Gun Club Pond were not possible with available data. The text has been modified accordingly.

Page 2-12, second paragraph, last sentence and Table 2.3

Comment 31. The area being discussed should be shown on a map. It is difficult to comment regarding the reasonableness of the stated values without a reference to this area. Obviously, the area is much larger than the RMA since many off-post recharge sources are discussed. However, some of the recharge values seem questionable. A discharge into the South Platte River of 37,600 to 56,600 acre-ft/year seems quite high. A 39-year average discharge of the South Platte River at Henderson is only 236,000 acre-feet/year. It is hard to believe that roughly one-fifth of this entire flow comes from ground-water discharges in the reach relevant to the RMA. Examples of some of the recharges that seem questionable include: 1) O'Brian Canal and Burlington Ditch--As stated in Appendix F, the estimated losses are for their entire length, not just those reaches within the Study Area; 2) North Bog--The North Bog has been used to recharge water that was withdrawn from the aquifer on the south side of the barrier system. If these withdrawals are not being accounted for in the

water budget, then accounting only for the recharge in the bog effectively results in double counting; 3) Recharge from the Denver Formation--Even if this value represents the entire modeling area, most of this recharge probably is attributable to sandstone subcrops within the RMA. We believe that 600 acre-feet/year (372 gpm) is probably not realistic. Of course it is difficult to comment on recharge estimates from irrigation or lateral flow at the Study Area Boundary without knowing the boundaries of the Study Area.

It is important for the text to recognize the uncertainty in many of the values listed in Table 2.3. For example, the value of recharge from Basin D is not based on any data, but is an assumed value.

Response The water budget calculations have been reviewed and revised accordingly. Inconsistencies have been eliminated. Estimates have been qualified with respect to uncertainty. Discharge into the South Platte River varied historically in response to changes in recharge conditions on RMA and adjacent land. Efforts to relate average discharge at Henderson to ground water discharge are inappropriate. Recharge along O'Brian Canal and Burlington Ditch have been revised in the table and a footnote added. Recharge due to the North Bog was accounted correct in the text. Recharge from the Denver Formation has been revised in Table 2.3. The study area was described in Section 1.0.

Page 2-13, Lateral Flow at Study Area Boundary

Comment 32. This value seems high. It would be useful to know the location of this boundary. As noted above, the limits of the study area should be defined.

Response The study area was defined in Section 1.0.

Page 2-13, Recharge from the Denver Formation

Comment 33. Even if this value represents the entire modeling area, most of this recharge probably is attributable to sandstone subcrops within the RMA. As noted above, we believe that 600 acre-feet/year (372 gpm) is probably not realistic.

Response Recharge from the Denver aquifer primarily occurs along sandstone subcrops. This is stated briefly on page 2-11 and described in greater detail in Section 2.5 and Appendix F. It is not possible to respond to a belief that the estimate is unrealistic without information to support the belief. As indicated in response to comment 31, the estimate has been reviewed and revised.

Page 2-15, second paragraph

Comment 34. Please clarify or explain why recharge is predominantly by vertical leakage through shale or claystone and not through more permeable sandstones, especially since the following sentence discusses head differences between the Unconfined Flow System and confined sandstones.

Response — As indicated in the comment, head differences have been noted between the Unconfined Flow System and confined sandstone of the Denver aquifer. In these cases, the confining rock is claystone or shale. Therefore, vertical flow in these areas occurs through the claystone or is negligible. Estimated rates are fairly small. In areas where sandstone is in direct connection with the Unconfined Flow System, head differences are negligible. Configurations of the bedrock surface and potentiometric surfaces are such that any water flowing from the Unconfined Flow System into subcropping sandstone, with a few exceptions in the vicinity of the Basin A Neck, must return to the shallow system in a short distance or flow deeper through a claystone interval.

Page 2-16, first paragraph, first sentence

Comment 35. The first sentence is confusing because quantitative estimates of recharge and discharge rates in the Denver aquifer are given on Tables 2.3, 4.1 and 2.4-6. Table 2.3 indicates that the Denver Formation recharges the Unconfined Flow System at the rate of 600 ac-ft/yr. Table 4-1 shows the Denver Formation is recharged by the Unconfined Flow System at the rate of 170 ac-ft/yr.

Response — See response to comment 31.

Page 2-16, second paragraph, last two sentences

Comment 36. The analyses for each lake given in Appendix F, Section 2.0, do not "verify" the mass balance calculations. They merely test whether the data are sufficiently accurate to show that recharge increases with an increasing water level in the lake. The analysis does not "verify" that the mass balance calculations are correct.

Response — The fifth sentence of the paragraph, indicating verification, has been revised to indicate that water level data have been reviewed for consistency with mass balance calculations.

Page 2-16, fifth paragraph

Comment 37. Statements made in this paragraph regarding surface-water ground-water interactions are incompatible with the Southern SAR text and with Appendix F, p. 2-80. The text states that ". . . mass balance calculations indicate net losses of water for both Lakes." Appendix F text states that ". . . Lake Ladora and Lake Mary gained an average of 14.0 and 1.4 ac-ft/mo, respectively, through ground-water discharge." Please ascertain the relationships.

Response — The text has been changed to conform with the Appendix.

Page 2-16, last paragraph, last line

Comment 38. The period(s) during which the estimates of recharge from Lake Ladora and Lake Mary were derived should be stated.

Response The period has been added to the text.

Page 2-17, first paragraph, second sentence

Comment 39. The period during which the estimates of recharge from the Havana Pond were derived should be stated.

Response The period has been added to the text.

Page 2-17, first paragraph, last sentence

Comment 40. See comment page 2-16, second paragraph, last two sentences.

Response In accordance with the response to the referenced comment (Comment 36), the sentence has been deleted.

SECTION 3.0: NATURE AND EXTENT OF CONTAMINATION

Page 3-12, third paragraph

Comment 41. Please list the OCPs that are included in this section and specify which compounds were manufactured at RMA.

Mention is made of OCP use on adjacent farms. However no mention is made of historic use of pesticides on the Arsenal by the Army. Comments regarding past pesticide use on-post should be added.

Response Organochlorine pesticides discussed in this section are identified in the second paragraph of the section. The text has been modified to indicate pesticide use on-post.

Page 3-13, third paragraph

Comment 42. Is the discussion of arsenic referring to dissolved or total arsenic?

Response The third paragraph of the section indicates that total arsenic is discussed.

Page 3-14, second paragraph

Comment 43. Please add a comment on drinking water standards for fluoride.

Response The suggested text has been added.

Page 3-16, third paragraph

Comment 44. Please add a comment on drinking water standards for chloride.

Response The suggested text has been added.

Page 3-18, third paragraph

Comment 45. The discussion would be clearer if the stratigraphic zone is identified along with the depth interval.

Response Zone designations have been added.

SECTION 4.0: CONTAMINANT ASSESSMENT

Page 4-2, Section 4.2

Comment 46. The relative importance of each mechanism to contamination migration at the site should be addressed in this section if possible.

Response Historic data are not available to evaluate the mechanisms during past periods when contaminants were introduced to ground water in large quantity. An analysis of migration through the vadose zone has been added to the text. It consists of an evaluation of migration potential under worst-case scenarios of unusually large precipitation and ponding.

Page 4-5, third paragraph

Comment 47. Figure 4.1 gives the incorrect impression that all ground water on RMA originates in the South Plants mound. This presentation should be corrected to avoid creating that impression.

Response Additional flow lines have been added to the figure indicating flow from areas south and east of RMA.

Page 4-6, Table 4.1

Comment 48. See comment page 2-12, second paragraph, last sentence and Table 2.3

Response See response for referenced comment (Comment 31).

Page 4-7, second paragraph

Comment 49. Change "cannot be correlated" to "do not extend."

Please point out that individual sandstones may not be correlative but fine-grained rocks and lignitic units have a greater degree of lateral continuity and are mappable across the area.

Response The suggested text revisions have been made.

Page 4-7, third paragraph

Comment 50. Please clarify that the paragraph is discussing horizontal hydraulic conductivity.

Response The text has been clarified to discuss horizontal hydraulic conductivity.

Page 4-8, first paragraph, last sentence

Comment 51. This sentence may be accurate. However, in the absence of an analytical evaluation of vertical migration and flow paths, it is misleading. We believe that an analytical evaluation of vertical extent of contamination would enhance this discussion and clarify numerous issues.

Response As stated in the Water Remedial Investigation Report and the Study Area Reports, the concentrations and mass of contaminants in the Denver Formation are generally 1 to 2 orders of magnitude less than in the shallow unconfined flow system. Mechanisms for contaminant transport from the unconfined flow system to the Denver sands have been identified in the Water Remedial Investigation Report in a qualitative manner. In addition, hypotheses have been presented for contaminant migration within the Denver Formation. A quantitative assessment of data for the Unconfined Flow System clearly indicates that rates of water and contaminant interchange between the two systems are substantially less than rates of movement within the Unconfined Flow System. In summary it can be stated that the nature and extent of contamination within the Unconfined Flow System is well defined and is more important (in terms of areal distribution and magnitude) than the contamination found in the Denver aquifer.

The Army agrees that additional efforts will be required to establish quantitatively the maximum depth of contamination and mechanisms for contaminant transport in the Denver Formation. The Army previously identified a general approach to assessing contamination at cluster well locations in the Denver Formation. This phased approach was described in Appendix D and Figure D-1 of the July, 1988, Draft Final Report, (version 2.3) of the Composite Well Program. The Army will address the issue through the Water Remedial Investigation subcommittee. The subcommittee includes representatives from the EPA, State of Colorado, Shell and the Army. The subcommittee will develop a detailed plan for evaluating the vertical extent of contaminant migration. A draft outline of the plan was provided to all Parties on June 12, 1989. The first meeting of the subcommittee is scheduled on June 22, 1989. Recommendations provided in comments in Study Area Reports and the Water Remedial Investigation Report will be evaluated and included in the detailed plan as appropriate. The Army anticipates that the detailed plan will emphasize interpretation of existing data to assess probable vertical extent of contamination. Upon completion of the detailed plan and review by the parties and the State, the plan will be implemented. Results of existing data interpretation will be described as an appendix to the Final Remedial Investigation Report.

Page 4-9, second paragraph

Comment 52. Please explain why the hydraulic interchange between the Unconfined Flow System and the Denver aquifer is important in areas where the volume of lateral flow is relatively low.

The fact that calibration was unsuccessful without the use of recharge in certain areas does not necessarily prove that the Denver Formation discharges into the UFS in these areas. Other explanations could be:

1.A different source of water than from the Denver Formation;

2. The original configuration of the water table (and/or conceptualization of the flow system) was not correct.

The distribution of calibration errors suggests that there was great difficulty in calibrating in the vicinity of the unlined basins. This is due, at least in part, to an assumption of steady-state and to the initial assumption that there must be flow from Basin F to the North Boundary System. In reality, there is currently very minimal (if any) flow in this region and the hydraulic gradient is very low. This is not to say that no discharge occurs from the Denver Formation into the alluvium. Discharge probably does occur, but it is probably significantly less important than indicated by the regional model.

Response The text was incorrect. The text has been changed to indicate that the model was sensitive to hydraulic interchange in areas where lateral flow was small.

Comments regarding the flow model are not entirely correct. Suggested alternatives for additional sources of recharge to the Unconfined Flow System are not supported by existing hydrogeologic data. The statement that little or no flow occurs from Basin F to the North Boundary is partly true. However, simulated flow in the HLA model also is small. The confidence expressed in the comment regarding reasons for head residuals in the vicinity of the Basin A Neck is not warranted.

Page 4-9, third paragraph

Comment 53. During the summer of 1988, MKE conducted four aquifer tests and measured the hydraulic gradients in the Basin A Neck (reported in Preliminary Engineering Design Package for the Basin A Neck Ground-water Intercept and Treatment System Interim Response Action, MKE, February 1989). It therefore is inappropriate to speculate on whether the model estimates of conductivity or flow (from an area with the "least favorable" calibration) are better than the values "originally inferred" without referring to the field data collected from this area. The aquifer tests showed the aquifer to be less permeable than shown in Figure 2.3.

Response Aquifer test data obtained by MKE in the Basin A Neck have not been published. Only the final result of the test analysis is provided in the referenced report. Consequently reliability of the results cannot be evaluated. Nevertheless, values obtained have been reported as estimates from unpublished data. Multiple-well tests resulted in values of 106 ft/day and 10.01 ft/day. Slug tests provided estimates of 0.09 ft/day and 24.09 ft/day.

Page 4-9, fourth paragraph, second sentence

Comment 54. During 1988, MKE conducted four aquifer tests and measured the hydraulic conductivity in the Basin A Neck (see above comment). Based on these data, the estimated flow through the Basin A Neck is 0.03 cfs.

Response The estimate by MKE is for that part of the Unconfined Flow System that is alluvium. At the referenced test location, the alluvium is in direct contact with unconfined Denver sandstone described by MKE as predominantly silty sandstone. This unit varies in thickness from approximately 5 ft beneath the deepest area of alluvium to nearly 30 ft along the north side of the Basin A Neck (Well 26058). Hydraulic conductivity of this unit was not evaluated by MKE. The estimate obtained by HLA with a numerical model probably is high due to calibration errors and errors in simulated hydraulic gradient. Because both estimates are uncertain, both have been referenced in the Water Remedial Investigation. Either way, the flow rate is small.

Page 4-9, last paragraph

Comment 55. There should be an explanation of how sensitivity relates to uncertainty. For example, if the model is used to estimate hydraulic conductivity, and the prediction of head simulated by the model is highly sensitive to hydraulic conductivity, there should be little uncertainty in the estimate of hydraulic conductivity.

Response The relation between parameter sensitivity and model reliability is substantially more complex than indicated in the comment. If a model is used to estimate hydraulic conductivity and all other parameters are accurately described, then large sensitivity indicates reliable estimation. In all other situations, the simple linear relation fails and parameter combinations need to be evaluated before stating that parameter estimates have little uncertainty. The model of flow beneath RMA falls in this latter category. Consequently, the addition of a statement like the one suggested would serve to mislead rather than inform the reader.

Page 4-10, third paragraph

Comment 56. As stated in this paragraph, the vertical model was used to perform sensitivity analyses. These analyses can provide valuable information on the dynamics of vertical flow but cannot calculate actual values (or range of values) of hydraulic conductivity due to the fundamental nonuniqueness of the model. Moreover, they cannot be used to determine ratios of actual hydraulic conductivity because our knowledge of the physical system is incomplete, and we are unable to constrain a system of equations sufficiently to obtain a unique solution. Simply stated, there are too many ways to obtain the same result. We are, however, able to derive from the sensitivity analyses hydraulic conductivity ratios that indicate the sensitivity of the model. In other words, a ratio of aquitard permeability to aquifer permeability would indicate the point at which the system becomes sensitive to leakage.

Response As indicated in the comment, the term sensitivity analysis was used incorrectly in this paragraph. The analysis actually consisted of initial evaluations typical of calibration exercises. Consequently, the term has been deleted from the paragraph.

Pages 4-10 and 4-11, Bullets

Comment 57. Please clarify explicitly which values refer to horizontal hydraulic conductivity.

Response The third and fourth bullets refer to horizontal hydraulic conductivity. The text has been revised to indicate horizontal hydraulic conductivity.

Page 4-11, second bullet

Comment 58. Actually, slug test results indicate that the hydraulic conductivity for Denver Formation sandstones ranges from $1x10^{-6}$ to $1x10^{-3}$ cm/sec.

Response The comment indicates that model estimates are within the range of slug test estimates.

Page 4-12, second paragraph

Comment 59. This paragraph incorrectly implies that effective porosity, specific yield, and bulk porosity are all approximately equal in the RMA Unconfined Flow System. The specific yields of fine-grained components of the aquifer are much lower than their bulk porosity. Even the high specific yields of sand, gravel, or sand and gravel generally are less than 0.30.

Response References to specific yield and bulk porosity are not critical to the discussion in this paragraph and have been deleted.

Page 4-13, second paragraph

Comment 60. This section is supposed to present a conceptual model of contaminant migration. However, the case for vertical migration of contaminants is not convincingly presented. For example, few of the possible mechanisms for vertical migration of contaminants are considered (e.g., poor well construction, intergranular flow through low permeability materials, etc.). Moreover, the mechanisms that are discussed (e.g., fracture clusters) are presented in a speculative fashion, without description of data that may support the interpretation. We believe that an analytical evaluation of the vertical extent of contamination and the mechanisms that may control this contamination should be conducted.

Response See response to comment 51. The section as originally written presented information that indicated intergranular flow through low permeability material is not a reasonable mechanism.

Page 4-14, first paragraph, fourth sentence

Comment 61. The statement that ". . . if migration occurs in networks of fractures, effective porosity probably is substantially less than 0.05" is misleading for two reasons. First it suggests that fractures do not improve the porosity of the affected media. This suggestion is not correct. Fractures can improve the porosity by 2 to 5 percent. More significantly, fractures can increase the permeability of a media, which is not mentioned. The focus on effective porosity, at the expense of other parameters such as permeability, is the second difficulty with this paragraph. The paragraph misleads the reader by suggesting that in fractured media, the effective porosity is small, and therefore the ability to transmit fluids is reduced.

Please expand on the concepts summarized by the last sentence. The interpretation that effective porosity is directionally dependent and that horizontal flow is preferential to vertical movement deserves more discussion.

Response The comment confuses the terms effective porosity and bulk porosity. In shale or media with discontinuous permeable lenses, effective porosity is controlled by interconnectivity of discontinuous permeable material. Fractures can enhance effective porosity of shale by substantial amounts if interconnected. Two to five percent is much too small a number. However, even with the substantial increase, the resulting estimate rarely exceeds 0.05. The comment is correct that fractures can substantially increase hydraulic conductivity. Several orders-of-magnitude changes are not uncommon if fractures are highly interconnected. Text to this effect has been added. Directional dependency in effective porosity of fractured media is poorly understood on theoretical grounds but well documented by multiple-well tracer tests in a variety of rock types and structural settings. It is an active topic of ongoing hydrogeologic research.

Page 4-15, fourth paragraph, third sentence

Comment 62. Change "the carbon-oxygen bond of a hydroxide ion" to "a hydroxyl group" and delete the following sentence.

Response The text has been changed as suggested.

Page 4-15, fifth paragraph, last sentence

Comment 63. Delete "to a lesser" extent. The phrase is misleading and suggests the process of photolysis reactions is less important in soil than in surface water.

Response The text has been changed as suggested.

Page 4-15, sixth paragraph, second sentence

Comment 64. The suggestion that little is known regarding biodegradation rates of target compounds is inaccurate because there is literature available discussing this subject.

Response Discussion of biodegradation has been added to Section 4.4. of the text.

Page 4-16, second paragraph

Comment 65. What is "MKE, 1986?"

Response The reference has been deleted.

Page 4-22, first paragraph, first sentence

Comment 66. "Vapor pressure" is not, by definition, "the ability of dissolved contaminants to volatilize from the liquid phase to the vapor phase." Vapor pressure is the pressure characteristic at any given temperature of a vapor in equilibrium with its liquid or solid form.

Response The text has been corrected.

Page 4-22, first paragraph, fifth sentence

Comment 67. Change "the organochlorine pesticides" to "the other organochlorine pesticides." Otherwise the incorrect implication is that dieldrin, mentioned in the previous sentence, is not an organochlorine pesticide.

Response The text has been changed as suggested.

Page 4-23, third paragraph

Comment 68. The statement that OCPs were "introduced to disposal basins in solution" is not correct and is an erroneous premise for the following sentence.

Please provide information that demonstrates that cosolvency enhances the mobility of organochlorine pesticides on the RMA.

Response The statement regarding organochlorine pesticides has been deleted in the revised text. Cosolvency is considered to be a possible mechanism for enhanced mobility. Additional possibilities include contaminant sorption on colloidal matter that migrates as a relatively nonsorbing compound, highly nonlinear sorption due to relatively small amounts of organic material in aquifer solids, and others. The paragraph has been rewritten to indicate that observed distribution is not consistent with distributions expected of large Kd compounds. Possible mechanisms have been listed.

Page 4-23, fourth paragraph, second sentence

Comment 69. The suggestion that DBCP "would only be present within short periods of time following disposal" is inaccurate. DBCP may remain in soils for 20 years or more following the last application.

Response The text has been changed as suggested.

Page 4-24, fifth paragraph, last sentence

Comment 70. It is not clear why compounds dissolved in surface-water and ground-water would be transported to the unsaturated zone. Please rephrase this sentence.

Response The phrase "to the unsaturated zone" has been deleted.

Page 4-25, third paragraph, last sentence

Comment 71. This sentence should be rephrased to indicate that mercury is more mobile than other metals but, depending on the oxidation state, is not necessarily mobile relative to other compounds in the environment.

Response The text has been changed as suggested.

Page 4-26, third paragraph, third sentence

Comment 72. Please change this sentence to "However, some transformations and degradations can yield products with increased toxicity, persistence, or mobility." The emphasis should be on products, not processes.

Response The text has been changed as suggested.

Page 4-26, third paragraph, last sentence

Comment 73. This statement is not universally true. For example, some analytes, such as TCE, degrade better under anaerobic conditions.

Response The text has been changed to include some volatile halogenated organics as exceptions.

Page 4-27, second paragraph

Comment 74. Including the chemical sewer, there are six major source areas. Please correct the paragraph to reflect this. Also, why is Basin C not considered to be a confirmed source?

Please clearly explain the differences between confirmed and suspected sources.

Lake Mary Overflow does not appear on the referenced figure.

Response The text has been changed to indicate six confirmed sources. Basin C is not treated as a confirmed source because contamination from Basin C may be masked by the presence of an upgradient source area. Differences between confirmed and suspected source areas are explained in this paragraph. Lake Mary Overflow has been deleted from the text.

Page 4-29, first paragraph

Comment 75. The references to "processed water cooling pond or isolated closed depressions" is unclear. Please be specific.

Response The references have been deleted.

Page 4-29, fourth paragraph

Comment 76. The flow path directions referenced on Figure 3.1 are not fully compatible with the text. Also, the flow paths are not entirely compatible with those in the South Plants SAR. The South Plants SAR identifies a southwest (i.e., South Tank Farm) plume rather than one trending south. More importantly, the flow paths shown for this area on Figure 3.1 are not the same as those in the South Plants SAR.

Response The text is consistent with the South Plants SAR. Figure 3.1 has been corrected.

Page 4-32, second paragraph, third sentence

Comment 77. Many of the contaminants detected in the Basin A source area were not found in wells installed in 1988 in the Basin A Neck. These data are presented in "Preliminary Engineering Design Package for the Basin A Neck Ground-water Intercept and Treatment System Interim Response Action" (MKE, February 1989). Those wells completed in the more permeable zones generally showed the least amount of contamination.

Response Many of the compounds detected in the Basin A Neck during 1987 occurred in concentrations less than the CRLs for the referenced Morrison-Knudsen data. In these cases, plumes of low concentration in the Water Remedial Investigation Report do not contradict the Morrison-Knudsen data. The Morrison-Knudsen data collected in 1988 would be more appropriately included in the 1988 annual report of CMP. This later report, currently in preparation, shows that some contaminants detected during 1987 were not detected in 1988. This is consistent with the Morrison-Knudsen data.

Page 4-37, second paragraph

Comment 78. What does "extensive deterioration" of the chemical sewer mean? When was leakage "known" to have occurred; by whom; and what was done about it?

Response Soil data presented in SARs indicate that the sewers probably leaked in many locations. Text has been changed to indicate probable deterioration of the vitrified clay. The work "extensive" has been deleted.

Page 4-39, third paragraph

Comment 79. We believe that mounding in the South Plants is not necessarily resultant from "enhanced recharge," but may be explained simply by the contrast in hydraulic conductivity between the alluvium and the bedrock mound.

Response The explanation given in Section 2.0 for mounding at South Plants is both enhanced recharge and contrasts in hydraulic conductivity. While it is clear that a contrast in hydraulic conductivity can cause mounding, it is not clear that the magnitude of the mound can be supported solely by the single mechanism. Until data are available to reject the hypothesis of enhanced recharge, it is prudent to consider both mechanisms as operable. Nevertheless the phrase in the text conflicts with text elsewhere in the report and has been deleted.

Page 4-40, second paragraph

Comment 80. Change "Ground-water travel time . . ." to "Ground-water travel time estimates . . . ."

The last sentence of this paragraph is misleading in that it implies that all plumes occurring north of the mound in South Plants are continuous with those from Basin A. This implication is not correct. Comparison of ground-water plume maps from the North Central and South Plants SARs shows that few of the plumes north of the mound in South Plants are continuous with plumes from the Section 36 lime ponds or Basin A. This indicates that migration has been much slower than 4.1 years. The Section 36 lime settling basins and chemical sewer may have been sources of contaminants for the plumes that occur in the southern part of Section 36.

Response Plume maps shown in the SARs are for groups of contaminants. Each group represents a range of sorption characteristics. Comparing the distributions of these groups with estimates of travel time is not appropriate. A review of both SARs shows that in cases where contaminant distribution is represented by multiple peaks along the flowpath toward Basin A, there is not sufficient separation of peaks to infer that each peak is associated with a separate source. The multiple sources identified along this flow path indicates that each peak may be associated with a separate source. On the other hand, several peaks could be associated with a single source. Either way, there is not sufficient confidence in migration history to justify a comparison between migration distance and estimated ground water travel distance.

Page 4-40, third paragraph

Comment 81. The Denver Formation is probably not unconfined in this area. Well logs indicate that the first occurrence of ground water at this location is within a thin horizon (< 1 ft) of apparently fractured claystones. Immediately above this zone is several feet of dry, hard, massive claystones. A layer of weathered claystone comprising the bedrock surface overlies the competent layer. This weathered zone is dry. The water in the permeable horizon exists under artesian pressure.

Response The confined conditions in the vicinity of these wells are likely to be very local in extent. On the regional scale considered in the Water Remedial Investigation Report, conditions generally are unconfined. Nevertheless,

when discussing the local area near these wells, references to unconfined conditions has been deleted from the text.

Page 4-40, fourth paragraph

Comment 82. The use of a hydraulic conductivity of 3 ft/day apparently is intended to represent the Denver Formation conductivity. When computing the travel time between from the South Plants area to Lake Ladora, the fact that some of the travel will occur in alluvial deposits should be considered. Moreover, the travel time through the vadose zone should be considered as well for all these calculations.

Response The estimates of travel time have been revised to account for movement in alluvial deposits. Travel time in the alluvium and unsaturated zone are substantially less than travel time in the Denver Formation. Revised estimates are given in Section 4.6.1.

Page 4-41, second paragraph

Comment 83. Saturated thickness of the Unconfined Flow System in the Basin A-Basin A Neck area, where it exists, is typically more, not less, than 10 feet. The highest value of hydraulic conductivity measured in a well by the aquifer tests in the Basin A Neck (see comment page 4-32, second paragraph, third sentence) is about 50 ft/day. However, the hydraulic conductivity of the more permeable portion of the aquifer encountered in the well was estimated to be about 100 ft/day or slightly more. Reporting the hydraulic conductivity indicated by the flow model in an area where the calibration was admittedly poor and actual field tests are available seems unnecessary.

Response Saturated thicknesses referenced in the text have been corrected. Saturated thickeness in Figure 2.2 was correct in the original version of the report. The Morrison Knudsen multiple-well test results have been referenced (10 ft/d and 106 ft/d) although test data and analyses have not be published.

Page 4-42, first paragraph

Comment 84. Where are the two secondary pathways referred to in the third line? Are these pathways confirmed or speculated?

Response Both are shown on Figure 3.1 in sections 25 and 26. The terminology of suspected and confirmed is more appropriately applied to source areas where historical records can be used to confirm a spill or other type of contamination. Konikow (1977 p.15) clearly indicates that the pathway in section 25 was important during periods when Basin A was filled. Evidence to support migration along the pathway in section 26 is less clear. Dilution of ground water by fresh-water recharge in Basin C has influenced the distribution of contaminants. As a result, most plumes are not portrayed as continuous along this pathway. The extensive distribution of dithiane and oxathiane in the Basin F pathway provides some evidence that the pathway in section 26 was important historically.

Page 4-42, second paragraph

Comment 85. Please explain clearly how the "areas of nearly continuous contamination" are defined. What does "nearly" continuous mean? Why are the control points and data not shown on the figures?

Response The term "nearly" has been deleted from the text. Patterned areas on Figure 3.17 represent areas where contaminant plumes have been identified in zones of the Denver Formation. The figures were compiled from Figures 4.2-23 through 4.2-28 and 4.2-30 through 4.2-34. Well control is shown on these figures and on corresponding point plots in Appendix D.

Page 4-43, second paragraph

Comment 86. How were the values of hydraulic conductivity selected? There is a great deal of uncertainty in these values as well as with the dynamics of the flow system. The ranges of velocity should reflect all sources of uncertainty. The effect of uncertainty on porosity is probably minor compared to other sources of error.

Response Estimates of travel time have been revised to reflect uncertainty in hydraulic conductivity.

Page 4-44, second paragraph

Comment 87. The first sentence is confusing and implies that source areas are located beneath Basins C and F when, in fact, the primary source areas are the basins themselves and not the substrate. The text does not indicate clearly the relationship between the pathways and the paleochannels. Please add a discussion on this subject if it is significant to contaminant migration.

Response The confusing text has been eliminated. Paleochannels are significant only if deep and filled with material that has substantially higher hydraulic conductivity than adjacent material in the Denver Formation. As became abundantly clear during the recent drilling by Morrison-Knudsen north of Basin F, paleochannels in this area are neither wide nor deep. A discussion of paleochannels in this area is not justified.

Page 4-44, second paragraph, last sentence

Comment 88. An alluvial aquifer test conducted just northeast of Basin F was reported by the U. S. Army Engineers Waterways Experiment Station to have a hydraulic conductivity of over 900 ft/day ("Report of Finding, Rocky Mountain Arsenal Pumping Tests", by Mark A. Vizpi, September 1978). Recent investigations by MKE have confirmed that the saturated alluvium north of Basin F, although now very thin, has a very high hydraulic conductivity. The low value of 1 ft/day reported in the text may be in error, or at least is not representative of the alluvial aquifer on the north side of Basin F.

Response The Vizpi test was included on Figure 2.3. The low value similarly was included. For completeness the Morrison-Knudsen value of 240 ft/d has been added. The low value is not representative of alluvium, but it is

representative of the Unconfined Flow System. The range will be reported on page 4-44.

Page 4-44, third paragraph, second sentence

Comment 89. The hydraulic gradient along the Basin F pathway shown in Figure 2.4 is higher than currently exists. Measurements made in 1988 by MKE showed the typical gradient to be approximately one-third as great as is shown in Figure 2.4.

Response The gradient estimated by Morrison-Knudsen in 1988 applied to a small area where the alluvium is saturated. Average gradients over a longer distance may vary from this estimate. Nevertheless, CMP data also indicate that gradients north of Basin F are changing. The reference to present day conditions has been changed to conditions during 1987.

Page 4-44, fourth paragraph

Comment 90. Basin C contained significant quantities of water as late as 1975. Because recharge from Basin C during its period of use was probably two to three orders of magnitude greater than present recharge, historic velocities probably exceeded present-day velocities by a factor greater than 5.

Response See response to comment 12.

Page 4-44, last paragraph, first sentence

Comment 91. This statement appears to be incorrect. The text states that the present-day velocity ranges from 1.0 to 4.0 ft/day. It also states that from 1957 to 1971 the average velocities were about 3 to 5 times greater than at present-day (apparently 3 to 20 ft/day). The 2.3 ft/day velocity estimated for DIMP (beginning in 1957) does not fall within this range.

Response This contaminant has migrated substantial distances since 1952. The text states that historical linear velocity probably was 3 to 5 times greater than present-day velocity within the area from Basin F to the north boundary. Gradients north of First Creek were not substantially different from today. Consequently, it is not appropriate to apply the factor of 3 to 5 north of First Creek.

Page 4-45, third paragraph, last sentence

Comment 92. The hydraulic gradient has been reversed along approximately one-half of the barrier, not the entire barrier.

Response The text has been modified as suggested.

Page 4-46, first paragraph, last sentence

Comment 93. This sentence should be revised to reflect the fact that the stated range applies to estimates of hydraulic conductivity.

Response Text has been modified as suggested.

Page 4-46, third paragraph

Comment 94. There are many sources of error in modeling contaminant transport, including unaccounted for aquifer heterogeneity, inaccurate aquifer parameters (hydraulic conductivity, effective porosity, and gradient), inaccurate chemical parameters, and so forth. Perhaps the fact that model predictions matched observed migration best with a retardation factor of 1.6 (rather than the value of 11 shown in Table 4.2) is evidence that the model does not adequately reflect actual conditions. It is inappropriate and misleading to assume that any discrepancies between predicted and observed travel times should be explained by the retardation factor.

Response If the only basis for varying the retardation factor from the value given in Table 4.2 was to obtain a better match to data, the comment would be correct and the adjustment would be inappropriate and misleading. However, the best estimate of retardation factor available at RMA for this contaminant is from a multiple-well tracer test conducted in the Western Tier. As indicated in the text, estimates between 1.0 and 1.8 were obtained from this test. Therefore, the value used on page 4-47 has a reasonable experimental basis.

Page 4-47, second paragraph

Comment 95. How do we know the rate of DBCP migration in the Western Tier? All we really know is the time the contamination was discovered, the present-day configuration of the plume, and the date Shell began producing DBCP. Very little is known about the source. We really do not have enough information to compute a travel time. In addition, retardation is not only a function of distribution coefficient but also a function of the organic content of the medium. The gravels containing DBCP contain minor amounts of organic carbon and very little clay. The retardation coefficient may be close to 1.

Response The travel time estimates for DBCP in the Western Tier have been deleted from the text because the approximate date of contamination is not known.

Page 4-47, fourth paragraph

Comment 96. What is the basis for the conclusion that the most extensive contamination of the Denver Formation is located in areas where sandstone or fractures provide direct hydraulic connection with contaminated ground water? Were other mechanisms evaluated? Without an analytical evaluation, this statement seems speculative.

The meaning of the last sentence is unclear. Please rephrase.

Response See response to comment 51. Geologic evidence in areas of greatest contamination in the Denver aquifer supports the statement. However, absolute proof of the mechanism is not available. Therefore, text has been modified to indicate the mechanisms as probable. The last sentence has been

rephrased to indicate that rates of lateral migration are not sufficient to have caused lateral migration in the Denver aquifer over great distances.

Page 4-48, first paragraph

Comment 97. It is unclear whether the reference to "some wells that obtain water from the lower sandstone" refers to the same zones. Please clarify this point.

This paragraph appears to be conjectural. Where are the data and analytical evaluation that substantiate these statements?

Response The text has been revised to indicate the number of wells obtaining water from each zone. Text has been clarified to indicate that the mechanism is probable. See response to comment 51.

Page 4-48, third paragraph

Comment 98. Other mechanisms explaining the isolated points of contamination should be discussed thoroughly in this section. The likelihood that isolated points are related to other factors, such as contamination while drilling or completing the well, poor well construction, false positives, laboratory contamination, etc., is equally plausible.

Response The identified mechanisms have been included in the text as possible.

Page 4-48, fourth paragraph, last two sentences

Comment 99. How can detections in sandstones beneath Zone A be described as "sporadic" when less than five wells are screened below the Zone A? The "sporadic" distribution may also be an artifact of few data points.

Response The text has been modified to indicate data are limited.

Page 4-49, first paragraph

Comment 100. The value of matrix hydraulic conductivity could be two orders of magnitude greater than reported. A range of values should be used to illustrate the accuracy of the values.

Response A range has been added to the text.

Page 4-49, second paragraph

Comment 101. This paragraph is speculative. The logs that describe fractures are describing the uppermost portion of the Denver Formation (i.e., claystones of the VC and VCE)--not down to or below Lignite A (LA). There is only one well that penetrates the LA in the central portion of the SPSA. The conclusions in this paragraph that vertical migration probably occurs along fractures in the South Plants is apparently not supported by data and should be deleted.

Response See response to comment 51. Data limitations below the lignite have been identified in the text.

Page 4-49, third paragraph

Comment 102. This section appears speculative. Only one well is located in Basin C and there are no wells located in Basin F.

Response Text has been changed to indicate that contaminants were detected near the basins rather than beneath the basins.

Page 4-49, last paragraph, continuing on page 4-50

Comment 103. This paragraph is confusing. The first statement indicates that the sandstones are separated by 10 ft of claystone and is immediately followed by a discussion of connection between the sandstones. The ideas presented here are speculative, with very little supporting data.

Response Confusing text has been clarified. Assumptions in this paragraph are clearly stated. The migration pathway is identified as possible. The assumptions indicate that it is not certain.

SECTION 5.0: SUMMARY AND CONCLUSIONS

Page 5-2, first paragraph, third sentence

Comment 104. Refer to comment page 4-41, second paragraph.

Response Initial estimates for model calibration were made prior to Morrison-Knudsen aquifer testing in the Basin A Neck. Consequently, the statement on page 5-2 is true. Although the model is relatively weak in this area, it is encouraging to note that the calibrated value obtained independently of Morrison-Knudsen test results is similar to those results.

Page 5-4, top of page

Comment 105. Other processes affecting contaminant concentration are not mentioned here. Are attenuation and dilution important?

Response The two processes have been added to the text.

TABLES: VOLUME I

Table 2.2

Comment 106. Change the title to "Estimated Hydraulic Conductivity for the Unconfined Flow System."

A footnote for "Hydraulic Conductivity" should be added to indicate the data source.

Response The present title essentially is the same as the suggested change. The footnote is not needed. The text describes data sources in greater detail than practical in a footnote.

Table 2.3

Comment 107. Define the Study Area. A number of the recharge sources are outside the RMA boundary.

It is unclear why Basin E is not considered to be a recharge area. "Lateral Flow at Study Area Boundary" is unclear.

Response The study area is defined in Section 1.0, page 1-2. Basin E recharge is discussed in Appendix F, Section 2.4. The phrase "lateral flow at study area boundary" has been clarified.

Table 4.1

Comment 108. The boundaries are not defined or indicated in the title. Two-thirds of the water volumes are off-site and downgradient. Only one-third pertain to RMA.

Please provide a reference for the data source.

Response The title has been clarified. Reference for the estimates was provided in the text.

Table 4.2

Comment 109. The discussion of environmental fate for dibromochloropropane should be corrected by: (1) changing "2-bromoallyl acid" to "2-bromoallylic acid"; (2) qualifying the statement "not persistent in soil to extent that it is an accumulation problem" as this statement could be misleading because it can be persistent in some soils and still be detectable after 20 years; (3) changing "radial" to "radical"; and (4) changing "oletins" to "olefins."

Response Table 4.2 has been changed as suggested.

FIGURES: VOLUME I

Comment 110. 1. Contours should be dashed where data are sparse.

2. All control points and data should be included on all the maps.

Response Control points have been added as suggested. Figures lacking control points generally were those showing geologic or hydraulic data for the Denver aquifer. Contour dashing has been reviewed and revised following addition of control points.

Figure 2.1

Comment 111. Change the thickness of Zone 4 "(036)" to "(0-36)."

Footnote for Zones 5 through 9 should read, "Zones poorly defined due to insufficient stratigraphic control."

Change the thickness for Zones 6 through 9 to read "(0-23)" etc. instead of "(to 23)."

Change note to "Not to scale. Net sandstone thickness shown in parentheses."

Change the title to "RMA Stratigraphic Column".

Response Suggested changes have been made.

Figure 2.3 (and Volume III, Plate WRI-18 and Figure 2.4-26)

Comment 112.This figure is misleading or inaccurate for the following reasons:

1. Does the map represent the surficial sediments or sediments directly overlying the Denver Formation paleosurface?

2. The explanation leads the reader to believe that the K values were derived only from pumping tests, yet the number of pumping tests is limited and does not support the detailed interpretation presented on the map. There are no pumping tests in the TKd unit, yet there is a K value and range presented for the "Denver Formation/Dry Alluvium". It is also unclear how a permeability is derived from a pumping test for a "dry" material.

3. Can the hydraulic conductivity derived from a limited number of pumping tests be extrapolated to all similar sediments? This assumption should be justified.

4. Please clarify whether the individual K values are arithmetic averages or another value.

5. Please check the values shown for the ranges in the Explanation. Qa3 indicates a range of $2x10^{-2}$ to 10^{-1}. However, a value of $2.8x10^{-4}$ is shown for the unit in Section 23.

Response

1. The map shows the areal distribution of hydrogeologic units of the Unconfined Flow System. The units are described in the text (Section 2.4 and Appendix F, Section 2.4). The map title has been changed to reflect this.

2. Hydraulic conductivity estimates are given in table 2.2 and Appendix B and have been deleted from the explanation. Aquifer test locations have been shown for the TKd unit. Reference to "Dry Alluvium" has been deleted.

3. The text indicates that values in table 2.2 are initial estimates subject to revision.

4. Text has been added to clarify the method used in obtaining "best" estimates.

5. Test values have been compared to estimates of ranges and needed adjustments have been made.

Figures 2.5 through 2.10

Comment 113.Concerns with these figures include:

1. The ground-water flow line arrows are all the same size, implying that the flow rate of ground water is the same in each direction. This is misleading.

2. The irregular dashed line along the northwest edge of each map is not identified. What does it represent?

Response 1. The explanation identifies the arrows as ground-water flow lines. No rate is implied.

2. The irregular dashed line represents the lateral extent of the zone. The figures have been modified to label the line.

Figure 2.10

Comment 114. Please explain the "dry" area appearing in Section 25 in the Explanation.

Response "Dry" area has been deleted.

Figure 3.1 (and Volume III, Figure 4.2-1)

Comment 115. It would be informative to include a figure showing surface water migration pathways. It would include migration pathways for surface water entering RMA from off-post via the Havana and Peoria Interceptors and the Uvalda and Highline systems.

A secondary pathway passes through the NWBCS. Is this correct?

Response Surface water migration pathways probably are coincident with the part of the stream system shown in Section 2.0 that is downstream from known points of contaminated surface water. The Quincy Street Pathway has been revised to show it starting northwest of the NWBCS.

Figures 3.3 through 3.9 (and Volume III, Figures 4.2-2 through 4.2-34)

Comment 116. The contour interval is irregular. To have utility, contour intervals must be consistent on each map.

Response Although uniform contour intervals are preferred, data distribution precludes this approach. The inference that maps with irregular contour intervals are without utility is incorrect.

Figure 3.10

Comment 117. This figure incorrectly implies that inorganic analytes are found continuously across alluvial/unconfined Denver Formation boundaries. This distribution is not supported by data and is probably not accurate since large contrasts in hydraulic conductivity occur across these boundaries.

Response The figure does imply that parts of the Unconfined Denver Formation have elevated levels of inorganic analytes. An example of this is an area in sections 22 and 23. Wells in this area have elevated concentrations of fluoride and chloride. The implication is correct.

Figures 3.10 through 3.27

Comment 118. Which inorganics are included on these maps? Mercury and arsenic should not be lumped together with other inorganics, but should be presented separately.

Figure 3.10 is so general that its usefulness is limited. The concentration ranges are missing. Are the concentrations of all compounds above background?

How were the shaded areas determined?

Many of the areas should be surrounded by dashed lines rather than solid lines. Data for deeper zones will be more limited than for shallower zones and the degree of uncertainty increases proportionately. Solid lines imply a certainty that may not be supported by the data.

Response The inorganic maps are based on the distributions of fluoride, chloride and arsenic shown in Appendix F. The organic maps are based on all organics discussed in Appendix F. Separate maps for these constituents are presented in Section 4.2 of Appendix F.

The purposes of these figures is to show the extent of contamination. They do not show precisely which contaminant is present at a location or the concentration at that contaminant. This information is given in Appendices D and F.

Shaded areas in Figures 3.10 through 3.27 are consistent with contoured areas of corresponding maps in Appendix D and F.

Solid and dashed lines are consistent with the approach used in contouring maps in Appendices D and F.

Figure 4.1

Comment 119. This map is misleading and incomplete. It implies that ground-water flow emanates largely from the South Plants area and entirely ignores the fact that ground-water enters the site upgradient from the southeast. Ground-water flow from upgradient is many times greater in volume than that flowing away from the South Plants area. The flow lines also imply that all flow rates are equally important and makes no attempt to differentiate between significant and insignificant flow paths. Several of the flow lines appear to pass through paleohighs without refraction in their directions. The arrows also incorrectly show that flow along the First Creek paleochannel by-passes the NBCS. Individual arrows should not cross the boundary containment systems.

Response Flow lines from the south boundary of RMA have been added. Flow lines indicate direction not magnitude of flow. Flow lines in vicinity of containment systems have been corrected.

Figure 4.2

Comment 120. The description of source "G" should explicitly state where the wastes in the Sand Creek Lateral were transported.

The ditches connecting the basins are not addressed even though they are potential contaminant sources.

Response Lateral were transported to disposal basins. Explanation H included reference to connecting ditches. The figure has been changed to indicate that wastes in Sand Creek.

PLATES: VOLUME I

Plates 1 and 2

Comment 121.1. We question whether these cross-sections illustrate an analysis of contamination pathways. We believe that without detailed qualification of flow, these cross-sections may be extremely misleading in that they incorrectly imply that vertical flow is more significant than lateral flow.

2. Soil, fill and disturbed areas have not been mapped, although they may be significant.

3. The "Sandstone Units" have lumped together sandstone and siltstone which have different hydrogeologic properties. The cross-section also shows this unit as continuous, when in actuality individual sandstones may be discontinuous and/or lenticular. This is misleading because the sandstone volume is increased by adding siltstone and the lateral distribution is erroneously displayed as continuous over wide areas--often without justification.

4. Some of the wells are hundreds of feet away from the line of section. Because of the discontinuous nature of the sandstones, projection and interconnection over large distances is misleading and may be inaccurate.

5. The isopotential lines imply a continuity within the Denver Formation which is not substantiated and may be inaccurate.

Response 1. The cross sections illustrate geology, head distribution, and flow paths. Titles have been changed to "Hydrogeologic cross section". Rates or quantities of flow are not implied.

2. Soil, fill and disturbed areas are not distinguished from alluvial and eolian deposits.

3. Sandstone and siltstone are combined for illustration purposes. By the same token not all sandstones have the same hydrogeologic properties. Sandstone is shown as continuous only when data on or near the cross

section indicate continuity. In other cases, sandstone is shown as discontinuous.

4. Because Plates 1 and 2 illustrate hydraulic head data it was important to locate the lines of section as close as practical along flowlines indicated on potentiometric surface maps for the Denver aquifer. Every effort has been made to select wells with reliable logs that are close to the line of section. Approximately one third are located more than 150 ft from the line of section. Distances from section are indicated. Geologic information has been reviewed for wells that are greater than 150 ft from the line of section and contacts dashed where appropriate.

5. Isopotential lines reflect continuity only where geologic units are shown as continuous.

Plate 1

Comment 122. The screened interval is missing for wells 27057 and 27058.

Response Screens have been added.

Plate 2

Comment 123. 1. The screened interval is missing from many of the wells (e. g. wells 37369, 23223, 23224, 23225, 26150, 01047, 01047, etc.)

2. Well clusters 26140 and 26141 should include Well 26142. Also the screened intervals appear incorrect. We do not have records that show a dieldrin concentration of > 80 ug/l for the year 1979 in Well 26141. Please check the data for accuracy.

3. The historical concentrations only show the samples which were above CRL and do not show samples which were not detected or BCRL. This is misleading when reviewing the plates. For example, "Historic DCPD" concentrations for Well 23007 shows a concentration of 200 ug/l in a sample dated April 1983, but it does not show the nine other samples taken in 1981 through 1983 which were not detected or were BCRL. Three samples were taken in 1984 were BCRL, one sample in 1986, and two samples in 1987 were also BCRL. Also not shown is a concentration of 7.0 ug/l from a sample taken in April 1985. If the intent is to show only the samples which had detectable concentration of an analyte then it should be clearly stated on the plates, which should then show total number of samples and total number of detections.

4. Our records show DBCP concentrations in Well 23053 for the same years as shown on the graph. However, the recorded concentrations are less than those shown on the Plate. The graph apparently has an incorrect scale. Please check the scales on all graphs for accuracy.

Response 1. Missing screens have been added.

2. Data for wells 26140, 26141 and 26142 have been reviewed as needed. Screens have been added. Dieldrin plats were correct in the original version.

3. A note has been added to indicate plots show samples with detections.

4. Scales for well 23007 have been checked. The scale was correct in the original version.

SHELL OIL COMPANY COMMENTS
DRAFT FINAL WATER REMEDIAL INVESTIGATION REPORT
VOLUME III (MARCH 1989)

SECTION 1.0: INTRODUCTION

Page 1-1, first paragraph, second sentence

Comment 124. Change "the Consent Decree (1988)" to "Federal Facility Agreement (1989)."

Response Text has been changed as suggested.

Page 1-6, second paragraph

Comment 125. Please include a statement that unlined Basins C, D, and E were also in use at this time.

Response Text has been changed as suggested.

Page 1-8, third paragraph, fourth sentence

Comment 126. Replace this sentence with the correct sentence shown on page 1-4, third paragraph, fourth sentence of Volume I.

Response Text has been changed as suggested.

SECTION 2.0: ENVIRONMENTAL SETTING

Page 2-2, second paragraph, third sentence

Comment 127. This sentence states that the rainfall for 1987 was 2.03 inches. This is incorrect and appears to be a typographical error. Should it be 12?

Response The typographical error has been corrected.

Page 2-10, third paragraph, first sentence

Comment 128. Change "Zones 7, 8, and 9" to "Zones 5 through 9."

Response Text has been changed as suggested.

Page 2-12, third paragraph

Comment 129. The statement "Sandstone occurs in Sections 2 and 25" appears to be incomplete since sandstones occur in many more sections than those two as shown in Figure 2.2-6.

Response The sentence has been deleted.

Page 2-14, fourth paragraph, third sentence

Comment 130. Unit AS is also mapped in Section 25 and the southeast corner of Section 26.

Response The suggested addition has been included.

Page 2-18, first paragraph, first sentence

Comment 131. This sentence implies that the Slocum Alluvium is predominantly fine-grained (clay and silt) material. However, gradation analyses performed on the Slocum Alluvium indicated that it consists mainly of gravelly sands.

Response Text has been changed.

Page 2-25, fifth paragraph, first sentence

Comment 132. Irondale Gulch does not originate in Montbello. We suggest replacing "south of the RMA in Montbello" with "southeast of the RMA."

Response Text has been changed as suggested.

Page 2-25, fifth paragraph, last sentence

Comment 133. We do not understand the suggestion that "none except the Sand Creek Lateral directly transmits water outside the boundaries of the RMA." If the intent is to describe surface water systems that carry water through the site and beyond the boundaries, the sentence should be clarified. The Sand Creek Lateral terminates on RMA and does not carry or transmit water downstream of the site.

Response The sentence was incorrect and has been changed to indicate that Sand Creek Lateral terminates on RMA.

Page 2-27, sixth paragraph, last sentence

Comment 134. Change "1957" to "1956."

Response Text has been changed to indicate that Basin F was constructed in 1956.

Page 2-40, sixth paragraph

Comment 135. A "relatively constant peak flow of 6 to 16 cfs" seems contradictory. If the range is between 6 and 16 cfs, the flow is not "constant."

The third sentence states that "Lake Ladora receives inflow from Sand Creek Lateral." Please rephrase the sentence to indicate that, although it is possible for the lake to receive inflow via the lateral, it does not routinely "receive" inflow from this source.

Response Text has been changed to eliminate "relatively constant" and clarify the relation of Sand Creek Lateral and Ladora Lake.

Page 2-41, fifth paragraph, sixth sentence

Comment 136. Please rephrase this sentence to indicate that, under normal conditions, Basin A drainage is internal.

Response Text has been changed as suggested.

Page 2-46, fourth and fifth paragraphs

Comment 137. Some consideration should be given to the effects of well construction on slug test results. Slug test results may not be representative due to these and other associated problems.

Response Text has been added regarding effects of well construction.

Page 2-51, third paragraph

Comment 138. The statement that "No consistent, discernible, seasonal patterns were detected in the hydrographs constructed from quarterly data" is misleading because it suggests that seasonal variations do not occur. Monthly data show strong seasonal variations (e.g. South Plants). Please rephrase the statement to indicate that seasonal variations exist in some areas.

Response The hydrographs of monthly data on Plates 1 and 2 clearly show seasonal trends. Text has been added to indicate that seasonal trends are noted in several areas when monthly data are considered.

Page 2-61, fourth paragraph

Comment 139. Hydraulic conductivities for RMA have been measured at less than 172.8 ft/day. Also, 910 ft/day equals 0.32 cm/sec, not 4 x 10^{-3} cm/sec, and is not significantly lower than values measured in coarser alluvium.

Response Values listed in the text have been revised to agree with Appendix B. Conversions from metric to English units have been corrected.

Page 2-66 and 2-67

Comment 140. Refer to comment on Page 2-12, second paragraph, last sentence and Table 2.3.

Response Refer to response to comment 31.

Page 2-71, second paragraph

Comment 141. We are not aware of any pilot plant associated with the Northwest Boundary Containment System.

Response Reference to a pilot plant has been deleted.

Page 2-74, first paragraph

Comment 142. Refer to comments on Page 2-12, third paragraph for Volume I.

Response Refer to response (comment 31).

Page 2-76, second paragraph

Comment 143. This paragraph should be rewritten. The implication that the ground-water recharge rate of 3.5 ac-ft/mo is constant is misleading. Please rephrase the sentence to indicate that the rate varies based on water levels. We disagree that losses from the lake are "detectable" in a well. What does "confidence interval" relative to lake levels mean? What does it mean to have lower levels statistically significant at the 95 percent level?

Response The recharge value is given as an average value. Text has been added indicating there are seasonal variations. The phrase indicating that recharge is detectable in the well has been deleted. The sentence describing 95 percent confidence intervals was not related to the discussion and has been deleted.

Page 2-77, fourth paragraph

Comment 144. The linear regression equation describing the relationship between lake loss and lake stage may be in error. Should this be Y = 17.67x - 234.7?

Response The text and Figure 2.4-27 have been corrected.

Page 2-79, first paragraph, first sentence

Comment 145. Please explain how the "Long-term trends in the well hydrographs also show recharge." Similar trends may also occur near a ground-water discharge.

Response As indicated in the comment, the paragraph was not relevant to the discussion and has been deleted.

Page 2-81, second paragraph, last sentence

Comment 146. The suggestion that water is "released from Havana Pond into Sand Creek Lateral to prevent overflow" should be rephrased to indicate that water could be released in this manner but only under unusual conditions, not under "normal" conditions. Has water ever been released into the Sand Creek Lateral to prevent overflow?

Response Text has been changed to indicate that releases are possible, not normal.

Page 2-90, first paragraph, last sentence

Comment 147. The suggestion that Basin D remains dry is incompatible with Table 2.4-6, which shows Basin D recharges the Unconfined Flow System at the rate of 50 ac-ft/yr. This rate was an assumed value based on a time period in which the basin contained water and may not reflect current conditions.

Response Table 2.4-6 has been revised to indicate negligible recharge beneath Basin D.

SECTION 3.0: SAMPLING AND ANALYSIS PROGRAMS AT RMA

Page 3-1, Section 3.0

Comment 148. This section is missing a thorough discussion of sampling procedure and methodology. Much of this information is inappropriately scattered through Section 4.0 and should be consolidated in Section 3.0. Sampling networks should also be discussed in this section.

Response The text indicates that sampling procedure and network selection are discussed in appropriate task reports. For Task 44, the text indicates that these topics are discussed in Appendix C.

Page 3-8, third paragraph

Comment 149. Change "unspecified herbicidal chemicals" to "2,4-D-like compound."

Response The text has been changed as suggested.

SECTION 4.0: NATURE AND EXTENT OF CONTAMINATION

Page 4-8, second paragraph, first sentence

Comment 150. Please explain why a smaller variety of analytes were detected during the 1987 sampling period than were detected previously.

Response Effects of dispersion and dilution would lower concentrations from historical values. Many analytes historically were near CRL. During 1987, concentrations probably were below CRL.

Page 4-13, first paragraph

Comment 151. The reference to the "South Plants Pond" is unclear. Which water body is indicated here?

There is no discussion of water quality of the lower lakes (Lake Mary, Lake Ladora, etc.) and this omission should be corrected. The water quality in the lakes is generally very good and deserves mention in this section.

Response The text has been clarified to indicate that the sedimentation pond in South Plants is being described. Discussion of water quality of the lower lakes has been added.

Page 4-14, third paragraph

Comment 152. Failure to analyze all samples collected during the Third Quarter 1987 sampling program for the same analytes limits the usefulness of the program. How can wells with different analyses be compared or mapped meaningfully

especially when much of the data are "summed" for presentation? Justification for this decision should be presented in Section 3.0 and in Volume I of this report.

Response Chemical constituents were analyzed by groups that were used in the summed approach. Failure to analyze for a group of constituents would result in no recorded data for all constituents within the summed group at a well. This would reduce the number of data points available for contouring but would not introduce bias to the summed presentation. Consequently the potential problem identified in the comment is a very minor one.

Page 4-20, first paragraph

Comment 153. Since alluvial ground-water characteristically has had higher concentrations of contaminants than Denver Formation ground water, we believe that those Denver Formation wells that "exhibit interaction" with alluvial ground-water should be included on the Unconfined Flow System maps only--not on both the Unconfined and Confined Flow System maps.

Response The suggested revision has been made for all contaminant maps of the Denver aquifer presented in Volume I and Appendix F. Point plots of contaminant distribution in the Denver Formation (Appendix D) use separate symbols to identify wells in confined and unconfined systems.

Page 4-20, second paragraph

Comment 154. The discussion of hydrogeologic controls on plume configuration is incomplete. Please rewrite the section to identify and describe thoroughly the hydrogeologic features influencing plume configuration (e.g., hydraulic conductivity, lateral continuity of sandstones, etc).

Response The discussion has been revised to clarify hydrogeologic controls on plume configuration.

Page 4-26, third paragraph

Comment 155. Please explain why the "organochlorine distribution is controlled predominantly by dieldrin and in a minor aspect by endrin." Is the distribution dominated by these analytes rather than controlled by them? Please clarify this.

Response The text has been clarified to indicate the dominance of Dieldrin rather than the control by Dieldrin.

Page 4-34, first paragraph

Comment 156. Please specifically identify those areas on the plume maps where historical data were used to draw the configuration of plumes, and qualify in the text that those areas may not be representative of plume configuration in the third quarter of 1987.

Response Areas where plume configuration are based on historical data occur in areas where samples were not obtained in 1987. Specific areas are identified in specific discussions of contaminants. In general plume configuration in these areas is represented by dashed contours. Control points sampled in 1987 also were shown on plume maps.

Page 4-34, fourth paragraph

Comment 157. Primary sources of contamination should be explicitly identified.

Response Primary source areas are discussed explicitly in Section 4.5 of Volume I. Detailed descriptions of each are included in study area reports. This section is substantially less detailed than Section 4.5 of Volume I. Therefore it has been deleted.

Page 4-39, fourth paragraph

Comment 158. The statement that "Many of these isolated occurrences may be related to dieldrin contamination identified elsewhere on-post" is misleading. Surely they are not related to contamination that is distant or downgradient from the isolated occurrences. If there is a relationship between isolated occurrences and contamination elsewhere on-post, please define the mechanism for the relationship and provide supporting data.

Response The text improperly suggests that isolated detections are related to on-post sources. Before identifying possible sources it is appropriate to confirm the occurrence of contaminant through resampling. Text has been modified.

Page 4-74, third paragraph, sixth sentence

Comment 159. The chlorobenzene occurrences referenced in this sentence are not shown on Figure 4.2-12.

Response A review of the data indicates the Figure 4.2-12 is correct. Therefore, the sentence has been deleted.

Page 4-80, third paragraph, last sentence

Comment 160. The use of the term "throughout" should be avoided in describing the distribution of analytes because it is misleading. In this case, a review of the map shows that VHOs are not distributed throughout the sections as indicated.

Response The word "throughout" has been changed to the word "in".

Page 4-84, first paragraph, second sentence

Comment 161. The statement "The plume begins at Wells 26085 and 26073 . . ." could be interpreted to mean that the wells are the source of contamination. Please rephrase the sentence.

Response The text has been rephrased to indicate that the upgradient end of the plume is near Wells 26085 and 26073.

Page 4-89, second paragraph

Comment 162. Please discuss the potential source areas for the "small" plumes described in this paragraph.

Response Plumes are based on insufficient data. Contours will be deleted and isolated detections have been shown for the two small plumes in Figure 4.2-15.

Page 4-94, last paragraph

Comment 163. The Quincy Street pathway is not shown on the referenced figure.

Response Reference to Quincy Street in the text is inappropriate and has been deleted.

Page 4-98, second paragraph

Comment 164. It is not clear how the plume can extend into the unsaturated alluvium in Section 36. Should this be "saturated alluvium?"

Response Unsaturated alluvium has been changed to unconfined Denver Formation.

Page 4-107, third paragraph

Comment 165. The reference to "Major irregularities" is vague. Please be more specific in the description of distribution. What is irregular?

Response Major irregularities have been changed to differences.

Page 4-107, fourth paragraph

Comment 166. Please explain why greater concentrations of dicyclopentadiene are reported from the 1984 investigation.

Response Reasons for the differences are not known. The Initial Screening Program final report indicates that the Spaine data (1984) were not confirmed by Initial Screening Program sampling.

Page 4-114, first paragraph

Comment 167. The reference to specific paleochannels by name is confusing because there is neither a map showing their location nor a description of any paleochannel by name. The introduction of paleochannels is also confusing because most of the previous discussion refers to pathways rather than paleochannels. Please clarify the relationship between paleochannels and pathways.

Response The term "paleochannel" has been changed to "pathway".

Page 4-126, first paragraph

Comment 168. The reference to "primary source areas" is unclear as source areas have not been previously defined for fluoride.

Response The phrase "principally associated with the primary source areas" has been deleted.

Page 4-128, first paragraph, last sentence

Comment 169. This sentence is speculative. If the lateral extent of the fluoride contamination in the eastern part of RMA cannot be defined, how valid is any comment on contaminant sources?

Response References to source areas has been deleted.

Page 4-129, fourth paragraph, last sentence

Comment 170. Please rephrase this sentence as the meaning is not clear. What is the suggested relationship between the fluoride plume and the Sand Creek Lateral?

Response The sentence is not relevant to the paragraph and have been deleted.

Page 4-130, last paragraph

Comment 171. Why are the fluoride plumes significant if the concentrations are mostly less than the maximum contaminant level? The maps are misleading because they show a wide distribution of fluoride although most of the fluoride is present at acceptable levels (less than 4,000 ug/l). Is the plume map meaningful?

Response The Water Remedial Investigation Report does not determine acceptable levels of contaminants. It reports distribution. The text makes no statement regarding significance of the plumes that are mapped.

Page 4-142, third paragraph

Comment 172. Acceptable chloride levels as defined by secondary drinking water standards are 250,000 ug/l. A bold contour with this concentration should be shown on each map so that the areas with significant concentrations are apparent.

Concentrations shown in Figures 4.2-30 through 4.2-34 appear to be in error by 1,000 ug/l.

Response See response to comment 171. Concentrations shown in Figures 4.2-30 through 4.2-34 are correct.

TABLES: VOLUMES III

Table 4.1-2

Comment 173. This table is misleading because it does not indicate what analytes were tested and does not indicate which ones were not detected.

Response Surface water quality data, including contaminants that were not detected, are given in Appendix B. A footnote has been added to the table.

Table 4.1-3

Comment 174. Please provide a footnote describing whether the mean represents an arithmetic or geometric mean, and how values below CRL were incorporated into the calculation of means.

Please provide an explanation as to why a range is reported for one detection. What are the units?

Response A footnote has been added to indicate that the mean is arithmetic. Units have been indicated.

Ranges for compounds with a single detection have not be shown.

Table 4.1-4

Comment 175. See comments for Table 4.1-3.

Response See response to comment 174.

Table 4.2-1

Comment 176. The title should reflect whether the wells are all screened in the Denver Formation.

Response Table 4.2-1 includes all sampled wells, including those in the Denver Formation and those in alluvium. Those screened in the Denver Formation were noted in Version 2.2.

Table 4.2-4

Comment 177. Which stratigraphic zones do the Point Plots depict?

Response Point plots for each analyte are presented for any zone where the analyte was detected. A footnote has been added.

Table 4.2-5

Comment 178. Does the "No. Samples" indicate the number of wells? Are multiple samples taken from each well? Were the samples all taken at the same time or over a period of time?

Response The word "samples" has been replaced by "wells". Multiple samples generally were not taken except for quality assurance/quality control purposes. Samples correspond to Third Quarter FY87.

Table 4.2-6 and All Similar Tables

Comment 179. Zones 5, 6, and 7 do not exist as Unconfined Flow Systems on the site and listing them on the table is misleading.

Response The tables have been changed as suggested.

FIGURES: VOLUME III

Figure 1.4-2

Comment 180. Task 44 is not shown on this figure.

Response The task area has been added to the figure.

Figures 2.2-5 through 10

Comment 181. The locations of data used to develop these maps should be shown.

Response Control points have been added.

Figure 4.2-11

Comment 182. Are the shallower Denver Formation zones free of benzene? Why does the map only show Zones 2, 3 and 4?

Response Shallower zones of the Denver Formation are not present in the mapped area. The zones were eroded prior to deposition of alluvium.

PLATES: VOLUME III

Comment 183. References, data sources, and explanations as to what data were used and how they were used is missing from the plates as well as the data used in preparing the plates. The reference "Source ESE" does not enable one to readily consult with the authority cited.

In areas where data are sparse, the detailed interpretation is unsubstantiated and the interpretation should be dashed.

Response Explanations for plates have been revised to clarify presented data. Methods used in constructing the plates also are described in the text at first reference. References were revised. In general, the reference "Source ESE" has proven sufficient to recover preliminary maps, data files, and so forth. Contours have been reviewed and revised as appropriate in areas of sparse data.

Plate WRI-5

Comment 184. The RMA boundary outline is incorrect, Basins A through E are not identified or are missing, and streams and roads are not shown. There are no symbols for disturbed or made land, fill or dams. The map is not compatible with SAR soil maps and should be replaced with the most recent soils map available.

Response The map was not used in the report and has been deleted.

Plate WRI-6

Comment 185. What does "Surficial Material" include? Does it include soils? Quaternary Deposits, Undifferentiated? Please be specific as the title is unclear.

Response "Surficial material" has been replaced by "Alluvial and Eolian Deposits."

Plate WRI-7

Comment 186. The meaning of "Channel Fill" is unclear. What is the age of this unit? The comment below the Legend suggests that the channel fill is not the same age throughout the area. The map shows all other units to be time stratigraphic units. Mixing "time-stratigraphic units" with one "rock-stratigraphic unit" is unconventional.

Identifying five units with the same symbol (in this case, as "blank") is misleading and confusing, especially since the units range in age from oldest to youngest. If the units are significant, then each should have its own map symbol. Also, there are several blank areas on the plate which are not identified.

Response Channel fill has been revised to indicate channel fill of undifferentiated age. This is consistent with the approach used in Morrison-Knudsen (1988).

Separate patterns have been added to the plate to differentiate the five units. Each unit has been revised to have its own map symbol. Blank areas without symbols on the revised plate are northwest of RMA and represent areas that were not mapped.

Plates WRI-9 and WRI-10

Comment 187. 1. No compass directions are identified for the cross-sections.

2. Change "Sand" to "Zone."

3. What is the vertical exaggeration? The horizontal scale is missing from Plate WRI-9.

4. There are two cross-sections designated as A-A' and B-B'.

5. Dates for water level measurements are not shown.

6. The symbols, "LA, LB, LC, LG" etc. are not identified.

7. Why is the topographic surface dashed? The topographic surface is confusing. The line of section is shown as a straight line on the index map and the cross-section implies that the wells are projected onto this line. Does the topographic surface reflect the line of section shown on the index map or does it reflect the topography of the wells used in the projection? This should be clarified.

8. There is no symbol for soil, fill, or made or disturbed land. The cross-sections misrepresent the surface materials by implying that the surface consists of "Fine Alluvium," which is not correct.

9. Some of the units appear to be steeply dipping. Is this the result of the vertical exaggeration, or are structural features implied?

10. The explanation of "NWB Upgradient 26.5" is incorrect. These lines do not represent cross-section match lines but are markers to indicate distance from a referenced point.

11. Wells thousands of feet apart are inappropriate for projection onto a line of section. Projecting wells from such large distances may result in misinterpretation of geologic features along the line of section.

12. An accurate stratigraphic column should be used to indicate the relationships between units.

13. The interpretation of lithology at the point of intersection between Plates WRI-9 and 10 is incompatible.

14. There are no marker beds. What is the basis for the interpretation of the stratigraphic zones?

Response Plate 9 shows information that also is shown on Plate 1 and has been deleted. Plate 10 has been revised as follows:

1. A location map has been added to show compass directions.

2. The suggested change is editorial and not needed.

3. Vertical exaggeration and scale have been added.

4. Letter designations have been revised to eliminate duplicates.

5. Date of water level measurements has been added.

6. These symbols are added to plate explanations as appropriate.

7. Topographic surface reflects the surface at the wells.

8. Cross sections have been reduced in scale to match scale of Plates 1 and 2. At the resulting scale it is not practical to show depths of soil.

9. Steeply dipping beds are not implied.

10. The addition of a vertical scale eliminates the impression of dipping beds. The explanation "NWB Upgradient 26.5" has been deleted.

11. Geologic features in the vicinity of wells that are greater than a few hundred feet apart have been dashed.

12. A Stratigraphic column is presented in Figure 2.1.

13. Incompatibility at intersections of cross sections has been resolved.

14. In areas where lignitic beds are not mapped, correlations are tentative and generally rely on matching sets of similar beds rather than matching individual marker beds.

Plate WRI-12

Comment 188. The plate states that the lignites are not continuous; therefore the contours should be dashed where the interpretation is uncertain. Strong bold contour lines imply a continuity that may not exist.

Response Interpretation has been reviewed and dashing has been used as appropriate.

Plate WRI-14 through 16

Comment 189. 1. The shading is missing from the unsaturated alluvium.

2. Several "bullseyes" may be artificial and should be examined for accuracy.

3. Contours are missing from Section 10.

Response 1. Shading has been improved.

2. Bullseyes have been reviewed and deleted as appropriate.

3. Contours have been added in section 10 where data support the addition.

Plate WRI-20

Comment 190. Cross-section B-B' is not located on this map.

Where is the plate that shows cross-section D-D'?

Response The location of cross-section B-B' has been added. The location of cross-section D-D' has been deleted.

STATE OF COLORADO

COLORADO DEPARTMENT OF HEALTH

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Rec'd
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1505

Roy Romer
Governor

Thomas M. Vernon, M.D.
Executive Director

May 5, 1989

Mr. Donald Campbell
Office of the Program Manager
for Rocky Mountain Arsenal
Attn: AMXRM-PM, Building 111
Commerce City, CO 80022-2180

Re: State Comments on Draft Final Water Remedial Investigation Report, March 1989

Dear Mr. Campbell:

Enclosed are the State's comments on the above-referenced document. The State appreciates your verbal extension of the May 1st deadline until today. If you have any questions regarding the comments, please contact Mr. Jeff Edson with this Division.

Sincerely,

David C. Shelton
Director
Hazardous Materials and
Waste Management Division

DCS/cf

Attachments

cc: Michael Hope
David L. Anderson
Chris Hahn
Edward J. McGrath
Connally Mears
Mike Gaydosh
Lt. Col. Scott Isaacson
Tony Truschel

RMA890611 1/2

STATE COMMENTS ON DRAFT FINAL WATER REMEDIAL INVESTIGATION REPORT, MARCH 1989

GENERAL COMMENTS

Comment 1. Vertical Extent of Contamination. The WRI Report does not present a definition of the vertical extent of contamination. Without this information, a major data gap exists in the RI/FS process. Consequently, it will not be possible to adequately assess potential remedial alternatives in the FS with respect to deep ground water contamination.

During the July 26, 1988 Water Media Subcommittee meeting, the State and the Army verbally agreed to jointly scope out and initiate further investigations to assess the vertical extent of contamination. As a first step, the Army informed the State that the WRI Report would evaluate the vertical extent of contamination using existing data. The evaluation of existing data would identify vertical boundaries where possible, the transport mechanisms, and any data gaps that prevent an adequate understanding of these issues. The WRI Report does not identify vertical boundaries, presents only a limited discussion of migration mechanisms (Section 4.7), and does not identify data gaps.

Regarding migration mechanisms, the State recommended that various deep migration conceptual models be developed and that each model be tested with existing data. The State was informed at various Water Media Subcommittee meetings that the Army had developed five conceptual models for vertical migration and that each model would be tested with the present Remedial Investigation data base. This work was not presented in the WRI Report.

Vertical migration in the Denver Formation is a concern because there is currently a downward hydraulic gradient, this downward flow is enhanced by density effects under RMA, and historically this downward flow was further enhanced by ground-water mounding. The WRI hints at the system conceptualization of downward flow in the Denver Formation until more permeable layers (sands and lignites) are encountered. At this point, some additional vertical flow occurs but much of the flow is diverted laterally in the permeable layer and flows towards the north and northwest. In this conceptualization, the more permeable layers in effect act as multiple barriers to downward migration. It is further conceptualized that lateral flow in the permeable layers is updip with the "assumption that flow from the Denver aquifer to the Unconfined Flow Systems occurs in all areas of subcropping sandstone." Remediation of the Denver Formation is an important concern. Therefore, the flow system conceptualization of the Denver Formation needs to be supported by data, not speculations and assumptions as is done in the WRI. An approach to verifying or rejecting this conceptualization is necessary before remedial alternatives for the Denver Formation can be considered.

Regarding vertical boundaries of contamination, the State's initial analysis indicates that in some areas of the Arsenal a general and broad boundary of contamination can be delineated. The basic groundwork was set for the WRI

Report in Figures 3.3 throughout 3.27 and Appendix D, which are contaminant detections mapped by water bearing zone. A logical progression would have been to present these findings in Section 3.2.1.2 - Vertical Extent of Contamination. However, only a brief discussion was presented. In addition, contaminant detections without an understanding of the mechanism (model) for how the contamination could have occurred is of little use.

The State recommends the following steps be taken to complete the review of existing data:

A. All deep Denver Formation monitoring wells that have anomalous or sporadic (non-repeatable) detections need to be resampled. This will provide the most comprehensive data set to assess deep aquifer detections.

B. Conceptual models need to be formulated for possible deep pathway migration mechanisms (e.g., cross contamination, historical vertical gradients caused by mounding beneath the basins, etc.). Data should be evaluated to confirm or refute each model.

C. An approximate boundary (e.g., specific sand unit) needs to be determined for particular areas of the Arsenal. Where data are sparse or confounding, the boundary should be noted as inferred.

D. Areas where data gaps exist need to be denoted. The need for additional monitoring wells must be assessed and prioritized.

Response

As stated in the Water Remedial Investigation Report and the Study Area Reports, the concentrations and mass of contaminants in the Denver Formation are generally one to two orders of magnitude less than in the shallow unconfined flow system. Mechanisms for contaminant transport from the unconfined flow system to the Denver sands have been identified in the Water Remedial Investigation Report in a qualitative manner. In addition, hypotheses for contaminant migration within the Denver Formation have been presented. A quantitative assessment of data for the Unconfined Flow System clearly indicates that rates of water and contaminant interchange between the two systems are substantially less than rates of movement within the Unconfined Flow System. In summary it can be stated that the nature and extent of contamination within the Unconfined Flow System is well defined and is more important (in terms of areal distribution and magnitude) than the contamination found in the Denver aquifer.

The Army agrees that additional efforts will be required to established quantitatively the maximum depth of contamination and mechanisms for contaminant transport in the Denver Formation. The Army previously identified a general approach to assessing contamination at cluster well locations in the Denver Formation. This phased approach was described in Appendix D and Figure D-1 of the July, 1988, Draft Final Report, (Version 2.3) of the Composite Well Program. The Army will address the issue through the Water Remedial Investigation Subcommittee. The Subcommittee includes representatives from the EPA, State of Colorado, Shell and the

Army. The subcommittee will develop a detailed plan for evaluating the vertical extent of contaminant migration. A draft outline of the plan was provided to all Parties on June 12, 1989. The first meeting of the Subcommittee is scheduled on June 22, 1989. Recommendations provided in comments in Study Area Reports and the Water Remedial Investigation Report will be evaluated and included in the detailed plan as appropriate. The Army anticipates that the detailed plan will emphasize interpretation of existing data to assess probable vertical extent of contamination. Upon completion of the detailed plan and review by the parties and the State, the plan will be implemented. Results of existing data interpretation will be described as an appendix to the Final Remedial Investigation Report.

Comment 2. Numerical Model of Ground Water Flow. Insufficient information is provided in the WRI to evaluate the numerical modeling; the reference HLA (Written Communication, 1988) is not provided in the reference section. Because of this lack of information, a detailed review of the modeling effort cannot be provided and findings of the study cannot be verified. However, the following general comment can be made. The model at some point needs to explicitly consider the hydraulically coupled nature of the Unconfined Flow System and the Denver aquifer. Currently, the two systems are only modeled as being coupled via leakage terms. Whereas this may be a necessary approach for the areal model (which only explicitly considers Unconfined Flow System) due to budget considerations, it is not necessary for the cross-sectional model, which only explicitly considers the Denver aquifer. The explicit coupling of the Unconfined Flow System and the Denver aquifer, along the data collection activities, is necessary to resolve the flow system conceptualization of the two systems. This explicit coupling is necessary before remedial alternatives for the Denver Formation can be evaluated.

Response A separate report describes the model. Entitled Regional ground-water flow modeling at the Rocky Mountain Arsenal, Denver, Colorado, the document has been released as a Draft Final Report, Version 2.1, March 1989. Explicit coupling of the Unconfined Flow System and Denver aquifer in a numerical model has not been done. This approach has been evaluated as described in general comment 1.

Comment 3. GC/MS Tentatively Identified and Unknown Compounds in Ground Water. The WRI has made very little progress in identifying GC/MS Unknown or Tentatively Identified Compounds (TICs). These compounds may be important toxicological impactors whose identification are crucial for the Endangerment Assessment. Further, positive identification of prevalent Unknowns and TICs is needed for full consideration of treatment alternatives in the FS.

The State has identified a list of prevalent TICs in RMA ground water. Upon analysis of specific chromatograms received from the Army, the State has determined that most of the TICs can be positively identified, and from the limited amount of data reviewed, a series of relatively lower boiling point semi-volatile hydrocarbons are positively identified. These findings are presented in an April 19, 1989 letter to Colonel Wallace Quintrell.

The Army must undertake the effort to positively identify all prevalent TICs and Unknowns in the ground water. Work should be started on those higher boiling point semi-volatiles tentatively identified as UNK 693/694, UNK 671/672 and UNK 642.

The positively identified petroleum related hydrocarbons must be incorporated into the FS, particularly in the analysis of treatment alternatives.

The Comprehensive Monitoring Program (CMP) must include additional GC analysis for the acid-extractable semi-volatile compounds. The effort is important to identify other semi-volatile compounds more directly than via the GC/MS screen.

Ground water from the recent (1987) series of monitoring wells in the North Plants Study Area has not been analyzed for non-target compounds using a GC/MS screen. This represents the only major source area that has not been investigated for non-target compounds. The CMP should include these wells as soon as possible.

Response

It is our understanding that the State is requesting that the Army identify all nontarget compounds which have been given a tentative identification. It is impossible to positively identify all "TICs." This is a result of the limitations of GC/MS technology and is not related to the level of effort that the Army devotes to the process. The GC/MS procedure results in the fragmentation of complex molecules into simpler ones. The instrument response consists of a series of mass/charge data points that constitute "fingerprints" for particular compounds or fragments of compounds. When all fragments are present and the fingerprint for each fragment is complete, then a positive identification of a compound can be made. When certain fragments are missing or the fingerprint for a particular fragment is incomplete, then it is not possible to identify conclusively the compound of interest. The probability that a given identification is correct is related to the number of fragments and the completeness of the fingerprints. GC/MS operators are trained to identify these fragments and fingerprints, and to a certain extent this process can be aided by the computer attached to the GC/MS instrument.

With TICs, the set of mass/charge data points is incomplete, so the operator uses his past experience and expert judgment in assigning compound identifications based upon incomplete data (fragments or fingerprints). This is why compounds are referred to as "tentatively identified." There is no way to recover the missing portion(s) of the chromatogram, so there is no way to improve the reliability or certainty of a tentative compound identification. Other GC/MS operators or chemists can review the chromatograms, and may have differing judgments about the identity of a given compound, but in any case, the result will remain an incomplete, uncertain, and tentative identification of a compound. Without a complicated and time-consuming process of tentative compound identification, certification of a more sensitive and definitive method to detect the tentatively identified compound (including spiking of samples to permit quantification of the compound concentration), and reanalysis of a new or collocated sample using the more sensitive technique, it is impossible to

positively identify all of the TICs. There is, of course, no assurance that the same TICs would be found in a new sample, and the old sample has certainly exceeded holding times, even if were not already discarded. A Water Remedial Investigation Subcommittee meeting will be held to further address this issue.

The Comprehensive Monitoring Program (CMP) has included analysis for acid-extractable semi-volatile compounds. The CMP also has included GC/MS analyses of wells in the North Plants Study Area.

Comment 4. The WRI Report does not have a section on data gaps. Without it, the reader is not aware of areas where uncertainty exists or where additional information is needed (e.g., North Plants ground water contamination). The Army has made no effort to summarize data gaps in this report or any of the Study Area Reports (SARs).

The State requested that an explicit section on data gaps be presented, and the Army agreed to provide it. An early version of the WRI outline (October, 1988 Technical Committee Meeting Notes) included such a section.

Response A data gaps section has not been added to the report. A Remedial Investigation data gaps section would have been included if existing data assessment indicated that data gaps existed. However, the Army believes the Remedial Investigation is complete, no data gaps exist, and sufficient information is available to begin the Feasibility Study. See general comment 1 for a discussion of additional investigation of vertical extent of migration within the Denver Formation.

Comment 5. There are numerous inconsistencies in the hydrogeological pathways between particular Study Areas. For example, the water bearing units designated in the South Plants Study Area do not correspond, and cannot be linked with, water bearing units in the Central Study Area and the North Central Study Area. It is important to delineate contaminant migration pathways from the deeper SPSA water bearing units to ground water north (CSA and NCSA) and south (SSA) of the South Plants. The WRI report does not provide sufficient detail to link these units.

Another example is the potentiometric surface of the Denver Formation Water Bearing Zone AM/AL in the Central Study Area. CSA Report Plate CSA-1.5-5 indicates that ground water flow in this unit is towards the northeast (towards First Creek). This contradicts regional flow maps in the WRI Report (Figure 2.4-10) (indicating northerly flow). Additionally there is no equivalent map for this unit for the North Plants Study Area in the NPSA Report. These inconsistencies must be resolved.

Response The identified inconsistencies have been resolved or justified in revisions to the text. In addition, internal consistency of all information has been reviewed and revisions have been made as appropriate. As a result, the potentiometric surface maps in both Central Study Area and Water Remedial Investigation Reports have been revised. Text has been added to the South Plants SAR relating water-bearing zones identified in that report to the aquifer system nomenclature used in the Water Remedial report. Water-

bearing zone 2 in the South Plants SAR is essentially equivalent to Sandstone zone. AM/AL in the Central SAR and Water Remedial Report. Contaminant migration pathways among the central, North Central, and South Plants SARs are consistent with the Water Remedial Investigation.

Comment 6. Suspected laboratory contamination of water samples presented in this report (e.g., methylene chloride) must be verified by resampling and analysis. Until proven otherwise, all suspected laboratory contamination should be considered as being representative of actual contamination.

Response A principal objective of CMP is to confirm distribution of contaminants detected in Water Remedial Investigation sampling. Suspected laboratory contamination is being evaluated as part of this effort. Water wells sampled during the Water Remedial Investigation with detected levels of contaminants have been recommended for inclusion in future CMP sampling. Most of the suspect wells already are part of the CMP well network.

Methylene chloride was detected repeatedly in laboratory blanks submitted as part of the quality assurance/quality control program. Concentrations reported for these blanks are similar to those reported for water well samples. For this reason, methylene chloride probably is not the result of contamination in ground water at RMA. Instead, methylene chloride is judged to be a laboratory artifact.

Comment 7. Each RI report should include a data quality assessment. Quality control evaluation results for all media sampled should be summarized in a separate section and also discussed as appropriate throughout the WRI report. The additional section should summarize laboratory quality assurance/quality control, blank contamination, and TIC results. In addition, the section should demonstrate the reliability of the database, document anomalies, and identify and verify laboratory problems.

Response Results of the data quality assessment are described in Appendix F, Section 4.3. Data used in this assessment are provided in Appendix D. Additional information specific to QA/QC for Task 44, including field procedures, is provided in Appendix C. The specific items listed in the comment are discussed in the referenced sections of the report.

Comment 8. The State has previously provided comments on draft and final technical workplans, and draft and final reports regarding water. To date, many of the deficiencies identified by the State have not been adequately addressed. Therefore, these previous comments and concerns are incorporated by references. The State expects the Army to provide a response to the principal comments and concerns raised by the State on the above-mentioned technical workplans and reports as part of the responsiveness package for the Remedial Investigation Report.

Response Comments previously submitted on technical plans and previous reports were appended with responses in the final versions of those reports. In the event that comments were not received from the State within the review period, and could not be included in the final reports, separate transmittals of

responses were distributed. Comments and responses that were not distributed previously are included as part of this appendix.

SPECIFIC COMMENTS

Comment 1. Section 1.1. The State strongly objects to the conclusion presented in this section that the Army investigations conducted to date fulfill the requirements of defining the nature and extent of contamination and completing a comprehensive RI for the on-post operable unit. Although the Army efforts are significant, there are many deficiencies and data gaps throughout the Army investigations that prevent a complete and accurate definition of the nature and extent of contamination at RMA. The State has identified many of these shortcomings in past comments and will continue to do so. Further specific remedial investigatory efforts are needed to comply with the minimum requirements of CERCLA and the NCP. Failure to conduct a complete investigation will result in a poorly designed or incomplete final remedy at RMA and a resultant failure to protect human health and the environment as required by statute and regulation.

Response The text in Section 1.1 will be modified to indicate that this report has been prepared in order to define the nature and extent of contamination as required by CERCLA. The phrase "fulfill the requirements of" will be deleted.

Comment 2. Section 4.5.1, South Plants Source Area and Pathways. The WRI Report neglects to indicate that free organic phase liquids may be present near South Plants. This contamination is suspected because of high aromatic concentrations in the ground water and historic spills of benzene (MKE, 1986, unpublished data), and because recovery wells were used at South Plants to attempt removal of free organic phase liquids. The recovery wells attempted unsuccessfully to remove dense nonaqueous phase liquids (DNAPLs), whereas the benzene would form a light nonaqueous phase liquid (LNAPL). Therefore, it is likely that both DNAPLs and LNAPLs exist at South Plants. NAPLs in the subsurface will greatly impact the FS and the remedial alternatives that need to be considered. The NAPLs have not been adequately characterized and their distribution is unknown. This represents a significant data deficiency.

Response Discussion of the possible presence of free organic phase liquids has been added. The number of wells sampled as part of the CMP in the vicinity of the suspected free-phase plume is substantially greater than in the Water Remedial Investigation. In addition, Shell/Morrison-Knudsen is conducting detailed investigations of the plume. It is anticipated that these efforts will sufficiently improve understanding of the character and distribution of free-phase contaminants. This additional information will be available for the Feasibility Study.

Comment 3. Section 4.5.3, Basin F Source Area and Pathways. The WRI should indicate if the deep injection well system was properly abandoned. This is of concern because the plugging and abandonment only occurred recently, and

the potential for cross contamination via leaks up the line existed for a number of years.

Response The Army recognized the potential for cross contamination associated with this well and began plugging and abandoning the well in October 7, 1985. Well casing was recovered during abandonment and was found to be in good condition without cracks or other evidence of cross contamination. Bond logs were run to ensure that well closure procedures were successfully achieved. A report describing the well closure titled, "Project Completion Report," Harrison Western Corporation, December 1985 is available at the RIC Center at RMA (RIC #88130R02).

Comment 4. Section 4.5.4, North Plants Source Area and Pathway. The Task 42 extended Phase I survey work was an initial ground water investigation at the North Plants. The State submitted comments that the Task 42 program and too few wells to meet the important objectives of this task. At present, the monitoring wells are able to define the local flow direction of the alluvial aquifer beneath North Plants, enhance the understanding of alluvial aquifer geometry, and provide some indication of contamination; however, the seven (7) monitoring wells cannot begin to fully identify source area contributions, localized extent of contamination in the alluvial aquifer, or localized hydraulic connection with the Denver formation. Additional monitoring wells must be located, based on the results of the first set of wells and the findings of the WRI and the North Plants SAR, to adequately determine the sources and extent of ground water contamination.

Response Based on discussions with all the parties, a total of 6 new wells was installed and sampled in the North Plants area. Data from the new wells combined with data collected from the previously existing well network have helped further define source areas, extent and rate of contaminants and interactions between the Unconfined Flow System and the Denver Formation aquifers. This new information has been included in the North Plants Study Area Report.

Comment 5. Section 4.5.7, Other Sources and Pathways (Also Figure 3.20). The Army has defined a very limited extent of contamination in the alluvial aquifer northwest of the Northwest Boundary Containment System. With the present monitoring network, it is impossible to delineate contaminants northwest of the Burlington Ditch. Sections 15 and 16 do not contain monitoring wells, with the exception of a few locations along their north and south section lines. Contaminants such as chloroform and DIMP historically have been detected in the area with the aid of consumptive use wells. A sketchy chloroform plume has been delineated in this area (Off-post RI Figure F-23), but too few wells exist to define the contamination with confidence. Ground water modeling investigations have shown this area to be a significant past contaminant pathway (Konikow, 1977). Although the northwest plume does not contain the number or concentrations of contaminants that the north plumes contain, it is still a significant pathway that must be fully investigated.

Response Potential for contamination along the Northwest Pathway is being evaluated as part of the off-post Remedial Investigation/Feasibility Study program.

Since preparation of the Water Remedial Investigation Report began, the off-post area has become a separate operable unit. All available off-post monitoring wells located downgradient (northwest) of the NWBCS have been evaluated as part of the off-post program and are currently included in the CMP monitoring network. Increased monitoring well density in this area would necessitate the installation of new wells. If such a modification is made in the future, the State will be provided an opportunity for additional technical input. Based on the Tri-County assessment of off-post wells that may be utilized in defining the extent of contamination northwest of the NWBCS, additional wells may be selected for future sampling. Consideration will be given to the installation of additional wells in this area if the need arises.

Comment 6. Section 4.6, Contaminant Migration and Alteration Along Major Ground Water Pathways. All flow calculations have been made assuming that the flow system is conservative, i.e., fluid density is constant. Unfortunately, chemical concentrations are sufficiently high enough to affect fluid density. For example, chloride concentrations greater than 1,000,000 ug/l were measured along the Basin A-Basin A Neck, Central, and Basin F pathways; the maximum concentration was 28,000,000 ug/l. For reference, sea water has a chloride concentration of 19,000,000 ug/l and a fluid density of 1.025 $g\backslash cm^3$. If all chemical concentrations are combined, the impact on density will be greater. Furthermore, historical concentrations were probably even higher. For example, when damage to crops north of RMA occurred in 1954, chloride content of wells within the off-post affected area ranged from 100,000 ug/l to 4,600,000 ug/l. Not only do these density effects influence horizontal flow, but because of the denser fluid, downward vertical flow and contaminant migration into the Denver Formation is increased. To more accurately characterize the flow paths, variable fluid density should be considered.

Response The higher ground-water density noted in the plumes in the northwestern portion of RMA will have little effect on flow patterns. the plumes are extensive, and assuming the density is uniform vertically, there should be no up or down component such as might occur with two fluids of contrasting density. Because most contamination occurs in the UFS, which is very thin vertically in relation to its length, the flow could not be distinguished from that of uncontaminated fresh water.

Increased migration downward into the Denver Formation due to density effects would be largely theoretical and not detectable from field data. A density increase of 3 or 4 percent represents an increase in head of that amount. Given that season water table fluctuations exceed this magnitude, the density factor is insignificant.

Comment 7. Section 4.6.1, South Plants Pathways. There is a significant chloroform plume present in Section 35 and Section 34. Its most upgradient detection does not correspond to a source. The plume appears to be migrating through the paleochannel in that area. A source of this plume has not been fully identified in either the North Central or South Plants SARs. The South Plants Study Area has extensive chloroform contamination that could be the source of this shallow ground water plume.

The State has recommended that monitoring wells be located in Section 35 to better delineate this plume (State Task 44 review comments). If these wells had been installed in a timely manner, the source of this contamination could likely have been identified by now. These additional monitoring wells are needed to determine this significant ground water pathway.

Response Several wells recently were installed to define the upgradient extent of this plume. Water quality samples from these wells will aid in identifying the source of the plume. Results of initial samples from these wells indicate that South Plants may be the source. The Water Remedial Investigation Report recognizes that the source is not confirmed. Instead, the text recognizes either South Plants or Sand Creek Lateral as possible sources.

Comment 8. Appendix F, List of Plates. The WRI Report should include a 1" = 2000' scale plate showing the "Depth to Water Table". Similar maps were contained in individual SARs. Plate WRI-13 may serve as a good base map for this endeavor.

Response Because the maps are included in SARs, we do not think it is necessary to duplicate the maps in the Water Remedial Investigation.

14 SEP

STATE OF COLORADO

COLORADO DEPARTMENT OF HEALTH
4210 East 11th Avenue
Denver, Colorado 80220
Phone (303) 320-8333

Roy Romer
Governor

Thomas M. Vernon, M.D.
Executive Director

September 8, 1988

Mr. Donald Campbell
Office of the Program Manager
Rocky Mountain Arsenal
AMXRM-PM, Building 111
Commerce City, CO 80022-2180

Re: State of Colorado's Review and Status of the RMA Water Media Investigation and Report

Dear Mr. Campbell:

This letter summarizes the outstanding issues regarding the RMA water media investigation. These issues were verbally communicated to the Army at the July 26, 1988, water media subcommittee meeting. Additional concerns regarding other aspects of the RI/FS will be addressed in the future.

The State has identified the following issues which may impact the sufficiency of the remedial investigation for water media. Furthermore, the State's review of the water media report outline indicated that some sections of the report need to be expanded. The State discussed those sections of the report with the Army at the July 26, 1988, water media subcommittee meeting.

A. Vertical Extent of Contamination

To date, no effort has been made to define the vertical extent of groundwater contamination. Without such an investigation, a major information gap will exist at the end of the remedial investigation. Consequently, it will be impossible to adequately assess potential remedial alternatives to address deep groundwater contamination in the FS.

During the July 26, 1988, water media subcommittee meeting, the State and the Army agreed verbally to jointly scope out and initiate further investigations to assess the vertical extent of contamination. During that meeting, the Army also informed the State that the water media report would evaluate vertical extent of contamination using existing data. The evaluation of existing

data will identify data gaps that prevent a complete understanding of the vertical extent and transport of contamination. The identified data gaps should be referenced in the water media report to determine whether the gaps need to be filled prior to evaluating remedial alternatives. The State hereby requests a written commitment that further investigations will be undertaken by the Army. The State is prepared to commit technical resources to scope out a viable workplan upon receipt of a written commitment.

B. Determination of Groundwater Pathways Within the Denver Formation

The need to assess groundwater contamination by hydrogeologic pathways in the Denver Formation, as opposed to wellpoint comparisons, is essential if appropriate remedial alternatives for Denver Formation contamination are to be developed.

At the July 26, 1988, water media subcommittee meeting, the Army informed the State that an assessment of the hydrogeologic pathways in the Denver Formation will be presented in the water media report. Army representatives indicated that this assessment will also include an analysis of fractured media as a transport mechanism. Data gaps found in this investigation should also be presented in the water media report.

C. Non-Target Compound Identification

While the Army has increased the coverage of monitoring wells for GC/MS screening to identify Tentatively Identified Compounds (TICs), the Army claims that most of the TICs cannot be identified.

The State reiterates that the Army should identify all TICs in the water media report. The State requested that the Army expeditiously provide copies of chromatograms of specific compounds on July 18, 1988, to make an independent determination as to whether the TICs can be identified. On September 1, 1988, an Army representative informed the State that there would be a long delay before the chromatograms could be provided to the State. These compounds are present in groundwater throughout the Arsenal in such significant concentrations that they must be identified so they can be incorporated into the Endangerment Assessment.

The State repeats its request for the expeditious production of the chromatograms to determine whether the TICs can be iden-

tified and to evaluate whether these compounds should be included on the target list for the Comprehensive Monitoring Program (CMP).

D. Spatial Extent of Contamination

The water media report should assess data gaps in the spatial coverage of monitoring wells based on the analysis of existing data. The new version of the Composite Well Program (CWP) appears to address some data gaps. The State will review the CWP and existing data and determine whether additional monitoring wells are needed.

E. Regional vs. Source-Specific Monitoring

Source-specific monitoring is necessary to determine whether a source area is contributing to groundwater contamination; to verify migration of contamination; and to identify local trends of contaminant distribution. These goals are distinct from the Task 4/44 regional monitoring program goals. RMA source-specific monitoring must be implemented as soon as possible. Source-specific monitoring is essential to integrate information about soils and groundwater in source areas and to fully characterize a source area. At the Task 23 meeting held on August 31, 1988, an Army representative informed the State that such a program will be implemented in the near future.

The State understands that the Army and Shell are reviewing source areas to determine what sites need specific groundwater monitoring wells. Upon receipt, the State will review this list and provide input on additional sources that need to be monitored.

F. Physical Characteristics of Compounds

The report should include a characterization of compounds detected in groundwater in terms of relevant properties including transport, volatilization, mobility and potential for degradation.

If you have any questions, please contact Jeff Edson with this Division.

Sincerely,

David C. Shelton

David Shelton
Director
Hazardous Materials and Waste
Management Division

DCS/PB/rw

pc: Michael R. Hope, AGO
David Anderson, DOJ
Connally Mears, EPA
Mike Gaydosh, EPA
Chris Hahn, Shell Oil Co.
Edward McGrath, HRO
Tony Truschel, GeoTrans

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RESPONSES TO COLORADO DEPARTMENT OF HEALTH COMMENTS ON THE WATER REMEDIAL INVESTIGATION TRANSMITTED IN SEPTEMBER, 1988 COVER LETTER

Comment A. To date, no effort has been made to define the vertical extent of ground water contamination. Without such an investigation, a major information gap will exist at the end of the remedial investigation. Consequently, it will be impossible to adequately assess potential remedial alternatives to address deep group water contamination in the FS.

During the July 26, 1988, water media subcommittee meeting, the State and the Army agreed verbally to jointly scope out and initiate further investigations to assess the vertical extent of contamination. During that meeting, the Army also informed the State that the water media report to determine would evaluate vertical extent and transport of contamination. The identified data gaps should be referenced in the water media report to determine whether the gaps need to be filled prior to evaluating remedial alternatives. The State hereby requests a written commitment that further investigations will be undertaken by the Army. The State is prepared to commit technical resources to scope out a viable workplan upon receipt of a written commitment.

Response See response to Colorado Department of Health comment 1 on the Water Remedial Investigation Report dated May 5, 1989.

Comment B. The need to assess ground water contamination by hydrogeologic pathways in the Denver Formation, as opposed to wellpoint comparisons, is essential if appropriate remedial alternatives for Denver Formation contamination are to be developed.

At the July 26, 1988 water media subcommittee meeting, the Army informed the State that an assessment of the hydrogeologic pathways in the Denver Formation will be presented in the water report. army representatives indicated that this assessment will also include an analysis of fractured media as a transport mechanism. Data gaps found in this investigation should also be presented in the water media report.

Response An assessment of migration mechanisms was provided in Section 4.7 of the Water Remedial Investigation Report. For additional response, see response to Colorado Department of Health comment 1 on the Draft Final Water Remedial Investigation Report dated May 5, 1989.

Comment C. While the Army has increased the coverage of monitoring wells for GC/MS screening to identify Tentatively Identified Compounds (TICs), the Army claims that most of the TICs cannot be identified.

The State reiterates that the Army should identify all TICs in the ground water media report. The State requested that the Army expeditiously provide composites of chromatogram of specific compounds on July 18, 1988, to make an independent determination as to the TICs can be identified. On September 1. 1988, an Army representative informed the State that there

would be a long delay before the chromatogram could be provided to the State. These compounds are present in ground water throughout the Arsenal in such significant concentrations that they must be identified so they can be incorporated into the Endangerment Assessment.

Response See response to the Colorado Department of Health comment 3 on the Water Remedial Investigation Report dated May 5, 1989.

Comment D. The water media report should assess data gaps in the spatial coverage of monitoring wells based on the analysis of existing data. The new version of the Composite Well Program (CWP) appears to address some data gaps. The State will review the CWP and existing data and determine whether additional monitoring wells are needed.

Response Several thousand ground water samples have been collected since 1985 to qualify and quantify ground water contamination in both regional and site specific studies; this number includes the extensive sample collection/analysis that has been conducted at each of the boundary containment systems.

Under the composite well program, prior to the summer of 1988, approximately 140 new monitor wells were installed (in part) to help fill perceived data gaps and to help assess spatial distribution of contamination. In addition, 6 wells have been installed as part of the Interim Response Action for the ground-water intercept and treatment system north of Basin F, and 11 wells were installed as part of the Basin A Neck ground-water intercept and treatment system Interim Response Action. A total of 36 new monitor wells will also be installed based on recommendations of ongoing Study Area Reports (SARs) and monitoring programs to further spatially define ground water contamination on a site-specific basis.

Over 400 wells were sampled during the Third Quarter FY87 and were used to construct Water Remedial Investigation Report plume maps. Historical data were also considered in Water Remedial Investigation Report assessments to provide a comprehensive understanding of both lateral and vertical ground water contaminant distribution. Because of this in-depth assessment, the Water Remedial Investigation Report was able to define major alluvial ground-water contaminant pathways at RMA that define the spatial extent of contamination. Perceived data gaps are also discussed in the Water Remedial Investigation Report.

Given the extensive data base, these recent interpretive works, and ongoing efforts to fill perceived data gaps, sufficient information is available to the Feasibility Study to determine Alternative Assessments. The purpose of the Remedial Investigation is to provide sufficient information for the Feasibility Study to recommend Alternative Assessments; should data gaps exist that impact these assessments, additional work may be necessary under the Feasibility Study.

Comment E. Source-specific monitoring is necessary to determine whether a source area is contributing to ground-water contamination; to verify migration of contamination; and to identify local trends of contaminant distribution. These goals are distant from the Task 4/44 regional monitoring program

goals. RMA source-specific monitoring must be implemented as soon as possible. Source specific monitoring is essential to integrate information about soils and ground water in source areas and to fully characterize a source area. At the Task 23 meeting held on August 31, 1988, an Army representative informed the State that such a program will be implemented in the near future.

The State understands that the Army and Shell are reviewing source areas to determine what sites need specific ground-water monitoring wells. Upon receipt, the State will review this list and provide input on additional sources that need to be monitored.

Response A review and assessment of source-specific monitoring was conducted in the September 27, 1988 Task 23 meeting. Please refer to the minutes of this meeting for more detailed discussions, recommendations, and results of the meeting.

As part of the Task 23 efforts, 16 Type III sites were identified in which contaminants present in soils might be in contact with ground water. Fourteen of these 16 sites currently have monitoring wells in place, either on a site-specific basis, or as part of a larger complex area of contamination. The remaining two sites are in areas covered by site-specific wells in the 36 Well Program. Ten of the 36 wells will help to fill site-specific data gaps.

Comment F. The report should include a characterization of compounds detected in ground water in terms of relevant properties including transport, volatilization, mobility and potential for degradation.

Response The Water Remedial Investigation Report includes discussion and tables that list the following characteristics of RMA ground-water analytes: Specific gravity, solubility, vapor pressure, Henry's constant, Kd, retardation factor (30% porosity, density - 2.7 g/cm3), and environmental fate. Also included in Appendix E of the Water Remedial Investigation Report is a discussion of the physicochemical properties and processes that may influence contaminant distribution.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VIII
999 18th STREET - SUITE 500
DENVER, COLORADO 80202-2405

Ref: 8HWM-SR

Colonel W. N. Quintrell,
Program Manager
Office of the Program Manager for
Rocky Mountain Arsenal
ATTN: AMXRM-PM
Building E4460
Aberdeen Proving Ground, Maryland 21010-5401

Re: Rocky Mountain Arsenal, (RMA),
Task 44, Final Technical Plan,
On-Post/Off-Post Ground and
Surface Water Monitoring Program,
March, 1988.

Dear Colonel Quintrell:

We have reviewed the above referenced report and have the enclosed comments from our contractor. Please call me at (303) 293-1528, if there are questions on this matter.

Sincerely yours,

Connally Mears
EPA Coordinator
for Rocky Mountain Arsenal Cleanup

Enclosure

cc: Thomas P. Looby, CDH
David Shelton, CDH
Lt. Col. Scott P. Isaacson
Chris Hahn, Shell Oil Company
R. D. Lundahl, Shell Oil Company
Thomas Bick, Department of Justice
David Anderson, Department of Justice
Mike Witt, ESE

88 1448 - 1/2

RESPONSE TO U.S. ENVIRONMENTAL PROTECTION AGENCY
COMMENT ON THE TASK 44 FINAL
TECHNICAL PLAN, MARCH 1988

Comment 1. Page 1, first paragraph. It is believed that sufficient information is available to complete the water related assessments for the RI effort. The data obtained in the Transition Monitoring Program (TMP) will not be utilized in the RI assessments unless the analyses indicate detections or trends other than those known or expected. EPA feels that use of the TMP data should not be qualified in this manner. All data which are available and of acceptable quality should be used to make the RI assessments which would include the most recently collected data under the TMP.

Response The Water Remedial Investigation is based primarily on data collected during the Third Quarter of FY87. Data collected as part of the Transitional Monitoring Program, obtained during FY88, were not available for inclusion in the Water Remedial Investigation Report. Those data are described in the Annual Report of the Comprehensive Monitoring Program currently undergoing internal review. Anticipated release date of the report is late June. Nevertheless data collected as part of the TMP will be used during Feasibility Studies.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VIII
999 18th STREET - SUITE 500
DENVER, COLORADO 80202-2405

Ref: 8HWM-SR

Colonel W. N. Quintrell
Program Manager
AMXRM-EE Department of the Army
U.S. Army Toxic and Hazardous Materials Agency
Building 4460
Aberdeen Proving Ground, Maryland 21010-5401

Re: Rocky Mountain Arsenal (RMA),
Task 4, Final Screening Program,
Third and Fourth Quarters Final
Report, May, 1988.

Dear Colonel Quintrell:

We have reviewed the above referenced report and have the enclosed comments. Please call me at (303) 293-1528, if there are questions on this matter.

Sincerely yours,

Connally Mears

Connally Mears
EPA Coordinator
for Rocky Mountain Arsenal Cleanup

Enclosure

cc: Thomas P. Looby, CDH
David Shelton, CDH
Lt. Col. Scott P. Isaacson
Chris Hahn, Shell Oil Company
R. D. Lundahl, Shell Oil Company
Thomas Bick, Department of Justice
David Anderson, Department of Justice
Mike Witt, ESE

SJ 1449-Y2

RESPONSE TO U.S. ENVIRONMENTAL PROTECTION AGENCY
COMMENT ON THE ROCKY MOUNTAIN ARSENAL
FINAL SCREENING PROGRAM, THIRD AND FOURTH QUARTERS
FINAL REPORT, VERSION 3.1
MAY 1988

Comment 1. Several EPA comments on the ISP report concerned the lack of comparison between historical data and ISP results. The Army responded that a thorough comparison was not possible because the historical data were inconsistent and of unknown quality. EPA suggested looking back at old field notebooks for information on past sampling procedures. The Army agreed with this comment and indicated that these records would be reviewed and discussed in the Final Task 4 report. This information is not presented in the Third and Fourth Quarters report. EPA recommends that this information be included in the appropriate Media report.

Response Old field notebooks contain insufficient detail to reconstruct past sampling procedures. Therefore, the quality of historical data may not be equal in quality to data collected since the Initial Screening Program. Nevertheless, historical data are useful for qualitative assessment and can be used to evaluate general plume configuration. Caution is needed, however, to assure that variations in ground-water flow direction and rate are evaluated when using data prior to the Initial Screening Program. The suite of analytes available in data collected prior to the Initial Screening Program also is much more restricted than the suite of analytes characterized in recent years. Similarly, well spacing is greater in historical data. Within these limitations, the Water Remedial Investigation Report includes discussion of the historical data for appropriate contaminants. These discussions are included in Appendix F, Section 4.2.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VIII
999 18th STREET - SUITE 500
DENVER, COLORADO 80202-2405

DEC 20 1988

Ref: 8HWM-SR

Mr. Donald L. Campbell
Deputy Program Manager
Office of the Program Manager
Rocky Mountain Arsenal
ATTN: AMXRM-TO
Commerce City, Colorado 80022-2180

Re: Rocky Mountain Arsenal (RMA),
Task 23 Source Area Monitoring Well
Plan for 37 Sites at RMA

Dear Mr. Campbell:

We have reviewed the above referenced proposed monitoring well plan. EPA proposes the following two additional monitoring wells to supplement the list of site-specific ground water monitoring needs recently proposed by EBASCO under Task 26: one well should be installed just northwest of Site 6-6 and a second well should be installed northwest of the washdown area in Site 31-4. EPA suggests a meeting of all parties to discuss the identified need for further monitoring well placement. Please contact me at (303) 293-1528, if there are questions on this matter.

Sincerely,

Connally Mears

Connally Mears
EPA Coordinator
for Rocky Mountain Arsenal Cleanup

cc: Thomas P. Looby, CDH
David Shelton, CDH
Patricia Bohm, CAGO
Lt. Col. Scott Isaacson
Chris Hahn, Shell
R. D. Lundahl, Shell
David Anderson, DOJ

RESPONSE TO COMMENT OF THE ENVIRONMENTAL PROTECTION AGENCY REGARDING TASK 23, SOURCE AREA MONITORING WELL PLAN

This comment was discussed during a June 6 Remedial Investigation Subcommittee meeting with the organizations and the State. The meeting was held to discuss issues of concern in the Eastern Study Area Report. As a result of the meeting the Army agreed to drill and complete a well downgradient and in the northwest corner of Site 6-6 as part of Feasibility Studies. At the meeting, it was agreed that the most upgradient well of five wells to be installed near the sanitary landfill also would serve as a well downgradient and northwest of Site 31-4. The minutes of this meeting are included as part of the Final Report of the Eastern Study Area.

HOLME ROBERTS & OWEN

ATTORNEYS AT LAW

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BOULDER, COLORADO 80302

EDWARD J. McGRATH

October 3, 1988

Mr. Donald Campbell
Office of the Program Manager
Rocky Mountain Arsenal, Bldg. 111
ATTN: AMXRM-PM
Commerce City, CO 80022-2180

Re: United States v. Shell Oil

Dear Don:

Pursuant to our understanding, and subject to the joint defense and attendant privilege provisions of paragraph 8.3 of the Consent Decree, enclosed please find comments on the Proposed Monitoring Wells Program which was presented at the September 27, 1988 Task 23 meeting.

With best regards.

Sincerely yours,

Edward J. McGrath by RT

Edward J. McGrath

EJM/mg

Enc.

cc: K. Blose
S. Isaacson
P. Chiaro (Ebasco)

RESPONSES TO
SHELL/MKE COMMENTS FOR TASK 23
ADDITIONAL PROPOSED SOURCE MONITORING WELLS

These comments have been prepared in response to the proposed site-specific monitoring well program presented by the Army and its monitoring and generally agree with the wells (or locations of new wells) selected by the Army. The few areas where we disagree or have concerns are summarized below.

Western Study Area
Proposed Wells 1 and 2:

Comment 1. Our principal concern with the proposed monitoring of Site 4-2 is that reliance on only two wells (one upgradient, one downgradient) is not sufficient to meet the stated objective of determining whether the "apparent soil contamination" is contributing to groundwater contamination. We would not argue with the desirability of having two monitoring wells installed closer to the supposed source. This would permit closer tracking of any changes in the relationship between upgradient and downgradient concentrations through time. However, unless it can be demonstrated that the two wells are aligned directly along the axis of the plume, differences in contaminant concentrations cannot be conclusively attributed to the presence of a source rather than to lateral variability.

Response Demonstrating that the two proposed wells are aligned along the axis of the plume will depend on the results of sampling from these wells. If the results are problematic, additional wells may be needed, but these wells should be located on the basis of data collected from proposed Wells 1 and 2.

Southern Study Area
Proposed Wells 3/4 and 5/6:

Comment 2. Fifteen Shell wells are located south and southwest of the benzene plume. Information obtained from sampling of these wells in Spring 1988 should help delineate the plume near Lower Derby Lake and the southern portion of Lake Ladora. We suggest that this recent data be evaluated to determine the need for additional wells or help in selecting new well locations.

Available data indicate that the benzene plume has a strong directional component to the west. If existing wells are shown to provide adequate coverage to the south of the plume, it would be appropriate for new wells to be installed farther west, between existing well clusters 02020//02021.02022 and 02034.02035.

Proposed Wells 7, 8, 9, and 10:

We agree with the need to understand the hydrologic relationship between the South Lakes and groundwater. However, it is not clear what these wells would add to the information already obtained from existing wells and water budget calculations.

Response Current data indicate that there is interaction between the lakes and the groundwater, but are not conclusive if recharge or discharge is occurring and if there is seasonal variation. If it is determined that the lakes are recharging the groundwater, then contaminants present in the lake sludges have the potential to migrate to groundwater. If the groundwater is recharging the lakes, then there is less concern that the lake sludges could contaminate the groundwater. These wells provide water level monitoring needs adjacent to the lakes.

Eastern Study Area
No comments.

South Plants Study Area
No comments.

North Plants Study Area
Proposed Wells 23, 24, and 25:

Comment 3. We agree that wells screened in the Denver Formation should be co-located with the alluvial wells where contaminants have been detected.

Response The comment has been noted.

Proposed Geophysical Survey:

Comment 4. We do not believe that the need for a geophysical study is supported by the geologic and hydrologic information provided to date, and we do not concur with the interpretation of a bedrock valley through the North Plants. We recommended that geologists from the parties meet to discuss this issue. We also suggest that the Army consider using nongeophysical methods such as drilling of additional bores, because of possible geophysical interferences in the North Plants (i.e., pipes, foundations, water table) and the degree of error surrounding interpretations of geophysical data. The cost-effectiveness of geophysical techniques as opposed to drilling or other investigative means should be considered.

Response Although we understand that there were opposing views as to the merits of conducting a geophysical survey in the North Plants Study Area, the Army felt that a survey of this nature would provide additional information useful to the overall interpretation of the hydrogeology in this area. This would then aid in the placement of the proposed alluvial wells.

The cost-effectiveness of the geophysical survey was indeed considered when choosing this investigative technique. It was believed that the geophysical survey would be more cost effective and comprehensive than would drilling of numerous bores. In addition, due to structures, pipelines and utilities located throughout the complex, locating and drilling of additional bores would have been impaired. These cultural interferences would be avoided with the seismic techniques to be employed.

Proposed Well 26:

Comment 5. We agree that a well upgradient from the site is desirable.

Response The comment has been noted.

Proposed Well 27:

Comment 6. We have no objection to an additional alluvial well in the manufacturing area.

Response The comment has been noted.

Proposed Well 28:

Comment 7. Installing a downgradient alluvial is desirable. However, a single well is probable insufficient to document the overall groundwater quality downgradient from the site. We suggest installing a total of three alluvial wells downgradient. Two wells to the south and east of proposed Well 28 would help delineate the plume.

Response Proposed Well 28 in association with Well 25048, located to the northeast, will be utilized to document groundwater quality downgradient wells, located to further define potential groundwater contaminants, may be installed at a later date, if warranted, based on analytical results obtained from Well 28.

North Central Study Area

Proposed Wells 29, 30, and 31:

Comment 8. We agree that additional wells near the Sand Creek Lateral would increase the knowledge base regarding area hydrology and groundwater quality. However, we believe that proposed Wells 29, 30, and 31 will not conclusively demonstrate whether the Sand Creek Lateral is a source of groundwater contamination. Therefore, we suggest that the program be modified to better address the stated objective.

Response Modifications or additions to the program will be considered after these wells have been sampled and the data has been evaluated.

Central Study Area
No comments.

APPENDIX H
COMMENTS AND RESPONSES TO THE WATER REMEDIAL INVESTIGATION, PROPOSED FINAL REPORT (VERSION 3.3) JULY, 1989

INTRODUCTION

Following the release of the Draft Final South Plants, Central, North Central and North Plants Study Area Reports ("SARs") and the Water Remedial Investigation Report, the Army responded to comments on those reports submitted by the Organizations and the State. In order to give additional consideration to matters which were not completely resolved during the comment period, and to avert the delay which may have resulted should one of the organizations have elected to invoke formal dispute resolution as provided for in the Federal Facility Agreement, Section XXX, the Army convened a formal subcommittee meeting on July 5, 6 and 7, 1989. Through this subcommittee and subsequent correspondence, revisions suggested by the Organizations were made to the Proposed Final Study Area Reports and the Proposed Final Water Remedial Investigation Report such that the organizations were satisfied that critical issues had been resolved. Additional noncritical concerns raised by EPA and Shell after the subcommittee meeting concerning the Proposed Final South Plants Study Area Report are responded to in this Appendix.

As the State is not a signatory to either the Proposed Consent Decree nor the Federal Facility Agreement, it is unable to invoke the Dispute Resolution Process. However, to insure that the State's substantive concerns received full consideration, issues raised by the State in subcommittee meetings regarding the Proposed Final South Plants Study Area Report are addressed in this Appendix.

Modifications in these reports resulting from the subcommittee's work are being sent to each recipient of the SARs and the Water Remedial Investigation Report, and together with the Version 3.2 Proposed Final Reports constitute the Version 3.3 Final Reports.

Rec'd
7/12/89
1115

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VIII
999 18th STREET - SUITE 500
DENVER, COLORADO 80202-2405

Ref: 8HWM-SR

Mr. Donald L. Campbell
Office of the Program Manager
Rocky Mountain Arsenal
ATTN: AMXRM-PM
Commerce City, Colorado 80022-2180

Re: Rocky Mountain Arsenal (RMA)
Proposed Final Remedial
Investigation Reports for the North
Plants Study Area, Central Study
Area, South Plants Study Area,
North Central Study Area, and the
Water Media, June, 1989.

Dear Mr. Campbell:

We have reviewed the above referenced documents and appreciate the several changes in each document made in response to our concerns. We have identified no concerns worthy of dispute, for the North Central, Central, South Plants, and Water Proposed Final Remedial Investigation Reports. As discussed at the meeting held on July 5, 1989, in regard to an issue of concern on the North Plants Study Area Report, we agreed to accept a commitment by the Army to assess during the Endangerment Assessment and the Feasibility Study the mobility and toxicity of methylphosphonic acid (MPA), a known breakdown product of dichlor. Therefore, we do not intend to raise a dispute over that document either.

However, we have several remaining specific comments on the Study Area Reports and the Water RI (see enclosure). Some of these address failures to modify the text, despite the stated intent in the response to comments. Others are matters which would result in an improved document and process, but do not appear essential to continued progress in the EA and FS; our suggestions remain and are part of the formal record. Please contact Linda Grimes at (303) 293-1262, if you have questions on this matter.

Sincerely,

Connally Mears

Connally Mears
EPA Coordinator
for Rocky Mountain Arsenal Cleanup

EPA REVIEW COMMENTS
WATER REMEDIAL INVESTIGATION REPORT
PROPOSED FINAL
Version 3.2
June, 1989

Comment 1. Recharge was not evaluated on a seasonal basis, as requested.

Response Rates of recharge vary seasonally but have caused relatively minor changes in water levels and groundwater flow paths. Although available data are sufficient to quantify annual rates of recharge, they do not allow quantification of seasonal variations in recharge. Therefore seasonal variations in recharge have not been discussed in detail.

Comment 2. No comparisons were made between historical groundwater data and RI data; however, temporal comparisons will be made in the future between RI data and CMP data.

Response As indicated in Appendix G, response to comment 28, the 1988 CMP Annual Report includes summaries comparing distributions observed in 1988 and 1987. The final version of that report was distributed June 30, 1989.

Comment 3. Potential sources of isolated contaminant detections in groundwater were not identified; if such detections are confirmed by the CMP, their sources will be postulated.

Response This comment is a restatement of the Appendix G response to comment 27. The Army agrees with this new comment.

Comment 4. Numerous Appendix D figures were not changed in response to EPA comments, although it was stated in the comment responses that these figures were changed.

Response A total of ten figures in Appendix D were questioned by previous EPA comments. Of these the Army indicated that changes would be made to D-59, D-82, D-109, D-137 and D-140. The Army regrets the oversight in not providing the modified figures in version 3.2 of the report. The corrected figures have been included in version 3.3.

Comment 5. Fluoride migration was not evaluated in detail; it was stated that CMP data are necessary before a detailed evaluation can be performed.

Response This comment is a restatement of the Appendix G response to comment 71. The Army agrees with this new comment.

Comment 6. No evaluation of laboratory QA/QC was included as requested. Since that evaluation was made in most of the CARs, a statement to the effect in the SAR Executive Summary would be appropriate and useful to the reader.

Response As indicated in Appendix G responses to comments 76 and 77, an evaluation of QA/QC data is included as Appendix F, section 4.3.3, and Appendix D.7. A statement has been added to the SAR Executive Summary.

Comment 7. Although the time for the fluoride-plume to reach the NBCS was estimated, the resulting impact on the treatment system was not addressed.

Response Evaluating the resulting impact on the North Boundary Containment System is not an appropriate task of the Remedial Investigation. It will be evaluated as part of the Feasibility Study.

Comment 8. Contaminant transport rates based on retardation factors were not evaluated.

Response As described in Appendix G response to comment 105, efforts to relate mobility of contaminants, as indicted by K_d or R values in Table 4.2, to observed contaminant distribution have not been successful. Causes for these differences are discussed in the Appendix G response to comment 105. If an improved understanding of transport rates based on retardation factors is needed during Feasibility studies, the mechanisms will be investigated as part of the Feasibility Study.

Shell Oil Company

c/o Holme Roberts & Owen
Suite 4100
1700 Lincoln
Denver, CO 80203

July 10, 1989

Mr. Donald L. Campbell
Office of the Program Manager
Rocky Mountain Arsenal, Building 111
ATTN: AMXRM-PM
Commerce City, CO 80022-2180

Re: Proposed Final Water Remedial Investigation Report

Dear Don:

Shell Oil Company appreciates the Army's responsiveness in addressing the issues raised by Shell's comments on the Draft Final Water Remedial Investigation Report ("Water RI"), as well as the issues raised during the July 7, 1989 meeting of the State and Parties (the Army, EPA, Shell and MKE) at the MKE offices. Based upon the agreements reached at the July 7 meeting, Shell does not wish to initiate dispute resolution on the Water Remedial Investigation Report. However, we reserve the right to invoke dispute resolution on any subsequent documents that utilize the information contained in the Water RI, or that utilize the Regional Ground-Water Flow Model.

The following items summarize the areas of concern to Shell and our understanding of the resolutions agreed upon by the State and Parties.

ITEM 1. Accuracy of the Regional Ground-Water Flow Model. We have two major concerns with the Regional Ground-Water Flow Model, which was incorporated by reference into the Water RI and has been used in drawing some conclusions discussed in the RI report. These two concerns are as follows:

1) The model oversimplifies the mechanisms of flow through both the "unconfined" and "confined" Denver Formation and exaggerates their degree of lateral continuity.

2) The numerical model exaggerates the significance of lateral flow through the Denver Formation. This results from overestimates of recharge from the Denver Formation, as well as overestimates of hydraulic conductivities of Denver Formation units and of eolian deposits in Basin A.

These concerns would be adequately addressed by inserting the following paragraph into the Executive Summary, preferably on page S-3 following the first full paragraph:

> "It should be recognized that the Regional Ground-Water Flow Model referenced in this report represents only one solution to flow in a very complex system. Due to the fundamental nonuniqueness inherent in all distributed-parameter models, values calculated from the Regional Ground-Water Flow Model are subject to uncertainty, and the model in its present form may not be sufficiently accurate for predictive purposes in all cases. Therefore, until such time as the model is refined and discrepancies resolved, extreme care should be used when modeling mass transport, determining boundary conditions for local models, or evaluating the effectiveness or regional impacts of remediation alternatives."

ITEM 2. Description of the Unconfined Flow System. We believe that neither the complexities within the unconfined Denver Formation nor differences in flow between this part of the UFS and the alluvium are adequately described. The following issues should be clearly conveyed:

1) Although the "unconfined" Denver Formation may be considered unconfined on a basin-wide scale, it may not be unconfined on a site-wide scale. These local complexities can have important implications to flow and transport. Therefore, it is important to mention in the report that ground water in the "unconfined" Denver Formation occurs under both confined and unconfined conditions, and that both saturated and unsaturated conditions can be found below the uppermost occurrence of water (i.e., water table).

2) Flow within the alluvium is essentially horizontal, and vertical gradients are not important on a regional scale. However, steep vertical gradients may exist in some areas of the RMA in both the confined and unconfined Denver Formation. This may make correlations difficult and may minimize the likelihood of lateral movement of contaminants over large distances.

We understand that the Army will consider revisions to the text and figures, as appropriate.

ITEM 3. Description of Flow in the Denver Formation. We do not believe that flow in the Denver Formation should be described as predominantly lateral. We understand that the Army will make revisions in the text of the Water RI to

describe flow in the Denver Formation as having both horizontal and vertical components.

ITEM 4. Hydraulic Conductivity Values. The vertical model cannot be used to defend a best estimate of 3.0 ft/day for the horizontal hydraulic conductivity for Denver Formation sandstone units. We understand that the Army will revise the text of the Water RI to report a range of K values (viz, 0.03-3.0 ft/day).

ITEM 5. Interpretation of Sandstone Continuity. In our opinion, the geologic interpretations shown in Plates WRI-1, -2, and -8 suggest that Denver Formation sandstones are more continuous laterally and vertically than may be justified. Specifically, sandstones and siltstones have been combined into units designated as "Sands" and are shown as correlative over many thousands of feet. In actuality, sandstone bodies are known to be lenticular, discontinuous, incompletely preserved, and much less extensive than suggested by the mapping unit designated as "Sands." We understand that the Army will change "Sand" to "Zone" on the plates.

ITEM 6. Migration Pathways through the Upper Denver Formation Portion of the UFS. Figures 4.2-1 (Volume III) and 3.1 (Volume I) present migration pathways through the "unconfined" Denver Formation in a manner that implies a greater knowledge of contaminant movement than we believe exists. For example, the figures depict migration pathways through the unsaturated alluvium (Denver Formation) that are not verified by data. We understand that the Army will revise Figures 4.2-1 and 3.1 to show pathways through areas of unsaturated alluvium with dashed arrows.

ITEM 7. Regional Ground-Water Flow Directions through the Upper Denver Formation Portion of the UFS. Figure 4.1, illustrating the potentiometric surface and ground-water flow directions of the unconfined flow system, remains of concern to Shell. We understand that the Army will revise Figure 4.1 to illustrate flow direction in areas of unsaturated alluvium with dashed arrows.

As an additional comment, this figure misrepresents the location of the South Plants ground-water mound, which actually straddles the north-south section line between Sections 1 and 2. The figure also falsely indicates that the South Plants area is underlain by saturated alluvium, whereas the area is actually underlain by unsaturated alluvium, and the water table is located in the unconfined Denver Formation. We understand that the Army will make appropriate changes to the figure.

ITEM 8. Fracturing in the Denver Formation. The discussion on the geology of fractures in Section 2.2.4.3 does not fully reflect the accumulated observations on the nature of fractures at the RMA. Based on a literature search and the regional setting of the RMA, we believe that deep-seated, continuous fractures associated with tectonic movement are probably not present in the Denver Formation at the RMA. However, we interpret fractures described in lithologic logs for some areas of the upper Denver Formation as being stress-release features associated with weathering and erosion of overlying strata. We understand that the Army will make appropriate revisions to the text.

ITEM 9. Use of the Water RI. The Army's response to Shell Comment No. 5 states that a "qualifier has been added to indicate that the purpose of the report is to provide a general overview on contamination." This qualifier is not present in the introductory statements of purpose in the Executive Summary, Section 1.0 of Volume I, or Section 1.0 of Volume III. The Water RI is a summary of the RI water data and should be used only for general, qualitative purposes. This point should be stated clearly in introductory remarks for the Executive Summary and Section 1.0 of Volumes I and III.

ITEM 10. Interpretation of Dieldrin Plumes at or Near the CRL. The interpretation of large areal extent of dieldrin plumes at concentrations near the CRL appears to be unsubstantiated. If these plume configurations are to be used during the FS, the water-quality data upon which they are based must be confirmed using dual-column or GC/MS selected ion monitoring confirmation techniques.

ITEM 11. Textual Changes. The Army's response to some of Shell's comments indicate that the requested changes were made to the text; in fact, many of the suggested changes do not appear in the text on the indicated page. We understand that the Army will re-examine the text relative to Shell Comments No. 18, 61, 74, 81, 96, 149, and 159.

ITEM 12. Comments on Additional Text. The present version of the Water RI includes extensive new text. Shell wishes to comment on this new text and requests a written response to these comments.

A. Page 4-3, third paragraph
The worst-case scenario assumes some unrealistic parameters. The equilibrium concentration of dieldrin in the water percolating through the top 5 ft of soil is calculated to be 3,700 ug/l. This is impossible because the maximum solubility of dieldrin in water reported by Table 4.2 is 84 ug/l.

B. Page 4-26, second full paragraph
It is not generally accepted that "soil persistence under laboratory conditions is approximately one order of magnitude less than field conditions." This conclusion, based on a single reference (Sparks 1988), is inappropriately extended to suggest that "application of laboratory data to the RMA site may grossly underestimate the length of time required for degradation of the chlorinated pesticides."

C. Page 4-26, third full paragraph
The statement that "dieldrin has migrated [in groundwater] from the vicinity of the South Plants area to both the North and Northwest Boundary Contaminant Systems" is unsubstantiated. In fact, dieldrin was transported to the basins by sewers and other mechanisms, not by groundwater. Solvents may have carried dieldrin from basins and sewers through the subsurface in the past; thus other transport mechanisms may account for "discrepancies" between ground-water flow rates and dieldrin distribution.

D. Page 4-27, second paragraph
Statements asserted in this paragraph are broadly generalized and incorrectly suggest that distribution coefficients cannot be used to estimate transport of RMA.

E. Page 4-27, third paragraph
The long persistence estimates presented for DBCP, with a half life of 140 years, may not be appropriate for the RMA. Biodegradation of DBCP and other analytes is highly dependent on environmental conditions and is highly variable. DBCP biodegradation will depend on anaeroic/aerobic conditions and other factors.

F. Page 4-33, second paragraph
The first sentence refers only to anaerobic processes, when in fact oxidative processes degrade these compounds in the environment.

G. Page 4-35, first paragraph
It is unclear which compound Vogel and McCarty demonstrated to be converted to 1,1-DCE and trans-1,2-DCE. In Shell's opinion, the compound could not be 1,1,1-TCA, but rather is probably 1,1,2-TCA (i.e., 1,2-DCE does not originate from 1,1,1-TCA).

H. Page 4-35, fifth paragraph
The statement that "[t]he presence of dichloroethylene within the TCE plume is indicative of the degradation of more chlorinated solvents" is confusing. Does this mean degradation from TCE or

from other "more chlorinated solvents?" Is it possible that dichloroethylene was an original contaminant, not a product of biodegradation?

I. Page 4-36, first paragraph
Is it certain that 1,1-DCE and 1,2-DCE are products of biodegradation of other compounds at RMA?

J. Page 4-36, second paragraph
The rate of decomposition of hydrazine in water suggested by the text (one or two days) seems too fast, unless the discussion is referring to oxidative biodegradation.

K. Page 4-36, third paragraph
The conversion of aldrin to dieldrin is well documented in soils and aqueous solutions, and it occurs even without biological activity whenever oxygen is present. The paragraph suggests that the groundwaters at RMA are anaerobic. Is this correct? What is the basis for the suggestion that groundwater may be anaerobic?

Please direct any questions or concerns regarding this letter to Julia Brown of MK-Environmental Services (303) 860-8621.

Very truly yours,

C.K. Hahn
Manager, Denver Site Project

CKH/ljb

Enc.

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SHELL REVIEW COMMENTS
WATER REMEDIAL INVESTIGATION REPORT
PROPOSED FINAL
VERSION 3.2
JUNE, 1989

Comment 1. Accuracy of the Regional Ground-Water Flow Model

We have two major concerns with the Regional Ground-Water Flow Model, which was incorporated by reference into the Water RI and has been used in drawing some conclusions discussed in the RI report. These two concerns are as follows:

1) The model oversimplifies the mechanisms of flow through both the "unconfined" and "confined" Denver Formation and exaggerates their degree of lateral continuity.

2) The numerical model exaggerates the significance of lateral flow through the Denver Formation. This results from overestimates of recharge from the Denver Formation, as well as overestimates of hydraulic conductivities of Denver Formation units and of eolian deposits in Basin A.

These concerns would be adequately addressed by inserting the following paragraph into the Executive Summary, preferably on page S-3 following the first full paragraph:

"It should be recognized that the Regional Ground-Water Flow Model referenced in this report represents only one solution to flow in a very complex system. Due to the fundamental nonuniqueness inherent in all distributed-parameter models, values calculated from the Regional Ground-Water Flow Model are subject to uncertainty, and the model in its present form may not be sufficiently accurate for predictive purposes in all cases. Therefore, until such time as the model is refined and discrepancies resolved, extreme care should be used when modeling mass transport, determining boundary conditions for local models, or evaluating the effectiveness or regional impacts of remediation alternatives."

Response As indicated in the subcommittee meeting of July 7, 1989, the Army agrees with the suggested insertion. Similar qualification also has been added to the body of the text in Section 4.3.2.

Comment 2 Description of the Unconfined Flow System. We believe that neither the complexities within the unconfined Denver Formation nor differences in flow between this part of the UFS and the alluvium are adequately described. The following issues should be clearly conveyed:

1) Although the "unconfined" Denver Formation may be considered unconfined on a basin-wide scale, it may not be unconfined on a site-wide scale. These local complexities can have important implications to flow and transport. Therefore, it is important to mention in the report that groundwater in the "unconfined" Denver Formation occurs under both confined and unconfined conditions, and that both saturated and

unsaturated conditions con be found below the uppermost occurrence of water (i.e., water table).

2) Flow with the alluvium is essentially horizontal, and vertical gradients are not important on a regional scale. However, steep vertical gradients may exist in some areas of the RMA in both the confined and unconfined Denver Formation. This may make correlations difficult and may minimize the likelihood of lateral movement of contaminants over large distances.

We understand that the Army will consider revisions to the text and figures, as appropriate.

Response — Revisions to version 3.3 of the report that reflect the complexity and uncertainty within areas of unconfined Denver formation have been added to Sections 2.4 and 4.3. Figures 3.1, 4.1, and 4.2-1 also have been revised to reflect uncertainty in locations of flow paths and contaminant pathways.

Comment 3 — Description of Flow in the Denver Formation. We do not believe that flow in the Denver Formation should be described as predominantly lateral. We understand that the Army will make revisions in the text of the Water RI to describe flow in the Denver Formation as having both horizontal and vertical components.

Response — Revisions to the report that reflect the complexity of flow in the Denver Formation have been added to Section 2.5 and 4.3. Statements to the effect that flow in the Denver aquifer may be predominantly lateral have been modified or deleted in Sections 2.5.2 and 4.3.1. The Army agrees that existing information does not conclusively demonstrate that lateral flow predominates in the Denver aquifer.

Comment 4 — Hydraulic Conductivity Values. The vertical model cannot be used to defend a best estimate of 3.0 ft/day for the horizontal hydraulic conductivity for Denver Formation sandstone units. We understand that the Army will revise the text of the Water RI to report a range of K values (vis, 0.03-3.0 ft/day).

Response — Table 2.2 of the Proposed Final Version of the report included a range of hydraulic-conductivity values (0.03 to 3.0 ft/day) estimated by aquifer tests. However text in Section 4.3.2 also indicated that a best estimate of 3.0 ft/day was obtained by modeling. This is not an appropriate inference of model results and has been deleted from the revised text.

Comment 5 — Interpretation of Sandstone Continuity. In our opinion, the geologic interpretations shown in Plates WRI-1, -2, and -8 suggest that Denver Formation sandstones are more continuous laterally and vertically than may be justified. Specifically, sandstones and siltstones have been combined into units designated as "Sands" and are shown as correlative over many thousands of feet. In actuality, sandstone bodies are known to be lenticular, discontinuous, incompletely preserved, and much less

extensive than suggested by the mapping unit designated as "Sands". We understand that the Army will change "Sand" to "Zone" on the plates.

Response — During the July 7, 1989 subcommittee meeting the Army agreed to change "Units" to "Zones" in the explanations of Plates 1, 2, and 8. This has been done. However, the Army understands the possibility of misinterpreting designations such as "Sand 1", "Sand 2", etc. Therefore, a note has been added defining Sand 1 to be the portion of Zone 1 consisting of lenticular and discontinuous sandstone, silty sandstone, shaley sandstone, sandy siltstone, and siltstone.

Comment 6 — Migration Pathways through the Upper Denver Formation Portion of the UFS. Figures 4.2-1 (Volume III) and 3.1 (Volume I) present migration pathways through the "unconfined" Denver Formation in a manner that implies a greater knowledge of contaminant movement than we believe exists. For example, the figures depict migration pathways through the unsaturated alluvium (Denver Formation) that are not verified by data. We understand that the Army will revise Figures 4.2-1 and 3.1 to show pathways through areas of unsaturated alluvium with dashed arrows.

Response — Migration pathways in areas where the water table occurs in the Denver Formation have been shown with dashed arrows to indicate that locations are approximate.

Comment 7 — Regional Ground-Water Flow Direction through the Upper Denver Formation Portion of the UFS. Figure 4.1, illustrating the potentiometric surface and ground-water flow directions of the unconfined flow system, remains of concern to Shell. We understand that the Army will revise Figure 4.1 to illustrate flow direction in areas of unsaturated alluvium with dashed arrows.

As an additional comment, this figure misrepresents the location of the South Plants ground-water mound, which actually straddles the north-south section line between Sections 1 and 2. The figure also falsely indicates that the South Plants area is underlain by unsaturated alluvium, and the water table is located in the unconfined Denver Formation. We understand that the Army will make appropriate changes to the figure.

Response — Figure 4.1 has been revised in version 3.3 of the report to show flow direction with dashed arrows in areas where the water table occurs in he Denver Formation. Dashing indicates that the directions are approximate. The figure also has been revised to indicate that the South Plants mound straddles the section line between Sections 1 and 2, and to correctly indicate the extent of unsaturated alluvium at South Plants.

Comment 8 — Fracturing in the Denver Formation. The discussion on the geology of fractures in Section 2.2.4.3 does not fully reflect the accumulated observations on the nature of fractures at the RMA. Based on a literature search and the regional setting of the RMA, we believe that deep-seated, continuous fractures associated with tectonic movement are probably not present in the Denver Formation at the RMA. However, we interpret fractures described in lithologic logs for some areas of the

upper Denver Formation as being stress-release fractures associated with weathering and erosion of overlying strata. We understand that the Army will make appropriate revisions to the text.

Response — Text indicating a decrease in fracture density with increasing depth below land surface has been added to Section 4.3.3 and Appendix F Section 2.2.4.3. Text has been deleted that implied fracture occurrence is related solely to presence of structural anomalies (Section 4.3.3). Statements regarding fracture mechanisms (tectonic vs stress release) have not been added to the text because evidence to support the statements would not be conclusive.

Comment 9 — Use of the water RI. The Army's response to Shell Comment No. 5 states that a "qualifier has been added to indicate overview on contamination." This qualifier is not present in the introductory statements of purpose in the Executive Summary, Section 1.0 of Volume I, or Section 1.0 of Volume III. The Water RI is a summary of the RI water data and should be used only for general, qualitative purposes. This point should be stated clearly in introductory remarks for the Executive Summary and Section 1.0 of Volumes I and III.

Response — Omission of appropriate qualifiers in the proposed final version of the report was an oversight that has been corrected in the final version. Statements qualifying the use of the report have been added to the Executive Summary, Section 1.0, and Appendix F, Section 1.0.

Comment 10 — Interpretation of Dieldrin Plumes at or Near the CRL. The interpretation of large areal extent of dieldrin plumes at concentrations near the CRL appears to be unsubstantiated. If these plume configurations are to be used during the FS, the water-quality data upon which they are based must be confirmed using dual-column or GC/MS selected ion monitoring confirmation techniques.

Response — Dual-column confirmation has been included as part of the CMP sampling during FY 1989 and will be reported in the 1989 Annual Report of CMP.

Comment 11 — Textual Changes. The Army's response to some of Shell's comments indicate that the requested changes were made to the text; in fact, many of the suggested changes do not appear in the text on the indicated page. We understand that the Army will re-examine the text relative to Shell Comments No. 18, 61, 74, 81, 96, 149, and 159.

Response — The text relative to these comments has been reexamined. Results are summarized as follows:

Comment 18 -- Although precise wording of the suggested text revisions was not followed, the substance of the suggested revision was included in Section 1.6.

Comment 61 -- The text addition was not made in the proposed final version of the report. The oversight has been corrected in the final version of the report.

Comment 74 -- The text in the proposed final version of the report (Section 4.5, paragraph 1) indicated five confirmed sources but listed six. The text in the final version has been corrected to indicate six confirmed sources.

Comment 81 -- The comment refers to conditions in the south-southwest pathway near South Plants (Section 4.6.1, paragraph 4). The comment response indicated that text changes would be made with respect to this pathway. The changes were made as indicated.

Comment 96 -- The oversight in the proposed final version of this report has been corrected. Section 4.7, paragraph 1 has been changed to indicate that migration through sandstones or fractures is probable not definite.

Comment 149 -- The oversight has been corrected. The text in version 3.3 of the report indicates "2,4-D-like compound".

Comment 159 -- The comment questions a sentence in Appendix F, Section 4.2.7.3, paragraph 3. The response indicated that the sentence would be deleted. The proposed final version of the report indicated that the sentence was deleted.

Comment 12 Comments on Additional Text. The present version of the Water RI includes extensive new text. Shell wishes to comment on this new text and requests a written response to these comments.

A. Page 4-3, third paragraph
The worst-case scenario assumes some unrealistic parameters. The equilibrium concentration of dieldrin in the water percolating through the top 5 ft of soil is calculated to be 3,700 ug/l. This is impossible because the maximum solubility of dieldrin in water reported by Table 4.2 is 84 ug/l.

B. Page 4-26, second full paragraph
It is not generally accepted that "soil persistence under laboratory conditions is approximately one order of magnitude less than field conditions." This conclusion, based on a single reference (Sparks 1988), is inappropriately extended to suggest that "application of laboratory data to the RMA site may grossly underestimate the length of time required for degradation of the chlorinated pesticides.

C. Page 4.26, third full paragraph
The statement that "dieldrin has migrated (in groundwater) from the vicinity of the South Plants area to both the North and Northwest Boundary Contaminant Systems" is unsubstantiated. In fact, dieldrin was transported to the basins by sewers and other mechanisms, not by groundwater. Solvents may have carried dieldrin from basins and sewers through the subsurface in the past; thus other transport mechanisms may account for "discrepancies" between ground-water flow rates and dieldrin distribution.

D. Page 4-27, second paragraph
Statements asserted in this paragraph are broadly generalized and incorrectly suggest that distribution coefficients cannot be used to estimate transport of RMA.

E. Page 4-27, third paragraph
The long persistence estimates presented for DBCP, with a half life of 140 years, may not be appropriate for the RMA. Biodegradation of DBCP and other analytes is highly variable. DBCP biodegradation will depend on anaeroic/aerobic conditions and other factors.

F. Page 4-33, second paragraph
The first sentence refers only to anaerobic process, when in fact oxidative processes degrade these compounds in the environment.

G. Page 4-35, first paragraph
It is unclear which compound Vogel and McCarty demonstrated to be converted to 1,1-DCE and trans-1,2-DCE. In Shell's opinion, the compound should be 1,1,1-TCA, but rather is probably 1,1,2-TCA (i.e., 1,2-DCE does not originate from 1,1,1-TCA).

H. Page 4-35, fifth paragraph
The statement that "(t)he presence of dichloroethylene within the TCE plume is indicative of the degradation of more chlorinated solvents" is confusing. Does this mean degradation from TCE or from other "more chlorinated solvents?" Is it possible that dichloroethylene was an original contaminant, not a product of biodegradation?

I. Page 4-36, first paragraph
Is it certain that 1,1-DCE and 1,2-DCE are products of biodegradation of other compounds ar RMA?

J. Page 4-36, second paragraph
The rate of decomposition of hydrazine in water suggested by the text (one or two days) seems too fast, unless the discussion is referring to oxidative biodegradation.

K. Page 4-36, third paragraph
The conversion of aldrin to dieldrin is well documented in soils and aqueous solutions, and it occurs even without biological activity whenever oxygen is present. The paragraph suggests that the groundwaters at RMA are anaerobic. Is this correct? What is the basis for the suggestion that groundwater may be anaerobic?

Response

Comments regarding new text in the proposed final version of the report were not raised by Shell during the subcommittee meeting of July 5-7, 1989. Nevertheless, the follow responses are provided.

A. Shell is correct in identifying a value of 3,700 ug/l as unrealistic. Therefore the worst-case scenario has been revised to use a value of 84

ug/l. This change does not alter the fundamental conclusions of the analysis provided in Section 4.2.

B. Text has been modified to indicate that persistence under laboratory conditions may be less than under field conditions and that caution is needed when using laboratory data to estimate degradation rates of chlorinated pesticides in RMA groundwater.

C. Shell is correct in indicating that the statement is not substantiated. The text has been changed to indicate that expected and observed behavior of dieldrin is not consistent.

D. The last sentence has been changed to indicate that simple linear models based on distribution coefficients given in Table 4.2 should be used with caution.

E. The paragraph has been modified to indicate that the estimate of 140 years is uncertain and subject to variation due to site-specific environmental conditions. The last sentence of the paragraph has been deleted.

F. The first sentence has been clarified to indicate that anaerobic conditions are discussed.

G. The paragraph contained a typographical error. It has been corrected in the final version of the report to indicate that the two compounds identified probably originate from trichloroethylene. This is consistent with Figure 4.2.

H. Shell is correct in identifying the text as confusing and possibly misleading. The text was intended to indicate that dichloroethylene is a product of biodegradation. The phrase "of more chlorinated solvents" has been deleted from the final version of the report.

I. The phrase "substantiating the hypothesis" has been changed to "supporting the hypothesis" to indicate that the mechanism is not certain.

J. The discussion refers to oxidative degradation. The text has been modified for clarity.

K. Previous discussion in this section of the report related to degradation of trichloroethylene presented evidence to support the hypothesis that oxygen may be limited in RMA groundwater. However, the hypothesis is not proven with certainty. Therefore, the last sentence of the paragraph in the proposed final version of the report was not appropriate and has been deleted.

STATE OF COLORADO

COLORADO DEPARTMENT OF HEALTH

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Denver, Colorado 80220
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Roy Romer
Governor

Thomas M. Vernon, M.D.
Executive Director

June 27, 1989

-HQ
Rec'd
7/5/89
1207

Mr. Donald Campbell
Office of the Program Manager
for Rocky Mountain Arsenal (RMA)
Attn: AMXRM-PM, Building 111
Commerce City, Colorado 80022-2180

RE: Army Responses to State RI Comments

Dear Mr. Campbell:

Attached is a listing of the specific Army responses to State comments on the Central, North Plants, North Central and South Plants Study Area Reports and Water RI Report with which the State continues to have substantial disagreement. The items are separated into three groups: those issues that the State wishes to raise for immediate resolution in the meeting(s) scheduled next week; those issues on which the State continues to disagree with the Army but due to time constraints or the nature of the dispute, may not lend themselves to further resolution in the scheduled meetings; and the source area "category" disputes which we also do not plan to discuss at this time. Upon a more thorough analysis, the State may raise additional concerns for discussion. The State also is preparing a list of areas requiring additional data collection.

Whether or not an item is identified as "disputed" in these or any other State comments package on RMA reports, the Army cannot assume that its responses satisfy the issues raised by the State's original comments. Regardless of Army responses, of course Colorado reserves the right to raise prior criticisms of any aspect of the investigations or remediation of RMA in any administrative or judicial proceeding that may ensue.

The items listed in the attachment are limited to certain technical concerns previously raised by the State. Issues regarding the application of the Colorado Hazardous Waste Management Act (CHWMA) and State comments that the activities conducted are either not

consistent with applicable guidance or do not fulfill the requirements of Federal and State law (e.g., CHWMA, RCRA, CERCLA, etc.) are not addressed herein except to notify the Army that the State's comments still stand and have not been adequately addressed.

Sincerely,

Jeff Edson
RMA Coordinator

Attachments

cc: Michael Hope
David L. Anderson
Chris Hahn
Edward J. McGrath
Connally Mears
Mike Gaydosh
Lt. Col. Scott Isaacson
Tony Truschel

Water Remedial Investigation Report

I. Technical Issues for Discussion

A. General Comment 1

Issue: The State expects the Army to agree to an approach for delineating the vertical extent of contamination.

B. General Comment 3

Issue: The State expects the Army to agree to an approach for positively identifying compounds.

C. General Comment 4

Issue: Numerous data gaps exist that must be documented. The State expects a data gaps section to be prepared. The State also will prepare a list of data gaps.

D. General Comment 6

Issue: The State expects a formal program to evaluate lab contamination. The CMP does not contain such a program.

E. General Comment 7

Issue: Data quality assessment was not adequately performed. Appendix F, Section 4.3 is not responsive.

F. Specific Comment 2

Issue: All areas of NAPL in South Plants must be delineated through actual sampling/investigation. The nature of the NAPL must be defined and the scope of the investigation expanded. Response is inconsistent with responses to South Plants SAR General Comment 5 and Specific Comment 4.

G. Specific Comment 4

Issue: Additional monitoring wells are needed to characterize North Plants area groundwater contamination.

H. Specific Comment 5

Issue: Additional monitoring wells are needed to characterize offpost northwest groundwater contamination.

I. Specific Comment 7

Issue: Additional monitoring wells are needed to characterize the South Plants chloroform plume.

II. Technical Issues Disputed but not Proposed for Discussion at this Time

General Comment

2

Specific Comments

3, 6

RESPONSE TO THE STATE'S LIST OF ISSUES ON THE PROPOSED FINAL SOUTH PLANTS STUDY AREA REPORT (Version 3.2) JUNE 1989

The Army met with the OAS to address their remaining issues and concerns in the subcommittee meeting held July 5, 6, and 7, 1989. The issues raised by the State have been previously addressed in numerous meetings, correspondence and formal responses prepared by the Army to comments on various products of the RI/FS process, including Technical Plans, Contamination Assessment Reports, and Remedial Investigation Reports.

As a result of the subcommittee meeting, the issues raised by the State and the Army's responses can be broadly subdivided as follows:

1. Issues on which the Army and the State continue to disagree;

2. Issues which are being addressed by specific investigation programs included in Interim Response Actions, the Comprehensive Monitoring Programs, and the Feasibility Study;

3. Issues which cannot be addressed until such time as the State provides to the Army the specifics of a site-by-site listing of their concerns, which the State has agreed to do at some later date; and

4. Those issues which upon discussion with the Army and further consideration, the State agreed to withdraw.

The Army reiterates its commitment to consider the State's concerns throughout the course of the Remedial Investigation/Feasibility Study process.